

# **Advancing Practical Physics in Africa's Schools**

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## Abstract

In countries with a long tradition of laboratory based teaching, practical work is seen by many teachers as an essential aspect of their practice. It is widely accepted that practical work not only enables skills acquisition but also leads to greater conceptual understanding. However, whilst there has been much research into the factors that affect teaching and learning of practical science across the economically developed countries, there has been little research into the existing conditions and the factors which affect teaching and learning of practical physics in African schools. This study provide the description of the present position and an analysis of possible beneficial interventions to the teaching and learning of practical physics in African secondary schools. The issues are relevant to all educational sectors.

Qualitative and quantitative data were collected from four countries in Africa. Surveys were carried out with 550 final year secondary school students and 44 secondary school physics teachers. Qualitative data were gathered from focus group discussions with the students and semi-structured interviews with; physics teachers, heads of science departments, school principals and ministry officials. Other key stakeholders including physics curriculum planners, physics educationalists from the tertiary institutions and voluntary Institute of Physics coordinators were also interviewed. The survey data were analysed numerically to produce descriptive statistics while qualitative data were transcribed and coded to provide easy retrieval of the themes that emerged.

The findings from the study reveal that there is a wide gap between practice in developed countries and the countries studied. This gap is attributable to many factors, some of which are predictable, e.g. various resource constraints. Other factors include ambivalent or negative teacher and pupil attitudes with prioritisation of 'theory' and a limited interest in or awareness of the importance of inquiry. These factors underlie the lack of practical physics assessment in some countries in Africa which is a further disincentive to practical physics engagement.

Based on the findings of this study, nine recommendations were made. Countries wishing to improve practice should undertake a broadly based audit of existing practice taking into account the full range of barriers and drivers. The physics curriculum should be reviewed to explore reduction of content to allow teachers spend time on practical activities. Initial training and continuous professional development of physics teachers should prioritise teaching of practical physics. Assessment of practical skills should be required for qualification and used formatively. Government funding should be allocated to build, equip and maintain adequate school laboratories. Physics teachers should be encourage to adopt the use of learning technologies and open source software in

the teaching and learning of practical physics. Physics teachers across Africa should be encouraged to use social media to develop a closer association that will spread effective practice. Teacher motivation should be enhanced by recognition of success in the delivery of practical physics. Students should be encouraged and motivated to learn practical physics by placing employability and relevant inquiry in the foreground.

This single study could only provide limited data on teaching across the continent. Further investigation is required before the conclusions could be generalised with complete confidence.

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## **Dedication**

This thesis is dedicated to the Almighty God who has made my dream to run this course a reality. Also, to my parent Mr Babalola Ezekiel Ojo and Mrs Babalola Agnes Morounmubo who inspired my love of education. I would especially like to dedicate this thesis to my grandmother, Mrs Babalola Aina, who was my inspiration but sadly, was unable to see me reach such heights.

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## Glossary of Terms

- **Laboratory activities**- activities which students are required to perform during laboratory sessions.
- **Practical work**- practical activities that include fieldwork, demonstrations, simulations, exercises, and observations or manipulations of real objects and materials by students. The students, typically working in pairs or small groups of three or four, are guided by their teachers and the teaching materials to observe and interpret events or phenomena. It includes physics experiments or demonstrations selected for the science students to do or observe at laboratory sessions. It also includes the hands-on activities used to teach and learn the concepts and theories of physics.
- **Laboratory facilities**- they are the materials, services and instruments needed when carrying out an experiment.
- **Effective teaching of (practical) physics**- this means the guidance of the students through (practical) physics activities in order for them to maximize learning.
- **Learning**- acquiring new knowledge, behavior, skills, values or preference. It may involve processing different types of information. It could also be seen as a relative permanent change in behavior that results from practice.
- **Student-centered approach**- methods of teaching that shift the focus of instruction from the teacher to the learners. Learners are required to actively think about or process information.
- **Teacher-centered approach**- teaching approaches where most of the class time is spent on teaching or lecturing while the students are watching and listening. The students work individually on assignments but collaboration is not generally encouraged.



## List of Abbreviations

- **CAPS**- Curriculum and Assessment Policy Statement
- **CPD**- Continuous Professional Development
- **CRDD**- Curriculum Research and Development Division
- **FET**- Further Education and Training
- **GDP**- Gross Domestic Product
- **GER**- Gross Enrolment Ratio
- **GET**- General Education and Training
- **GPI**- Gender Parity Index
- **ICT**- Information and Communications Technology
- **IoP**- Institute of Physics
- **IVPL**- Internet Virtual Physics Laboratory
- **IwebP**- Interactive Web quest Packages
- **NCTE**- National Council of Tertiary Education
- **NERDC**- Nigerian Educational Research and Development Council
- **NFER**- National Foundation for Education Research
- **NPE**- National Policy on Education
- **OU**- Open University
- **PhET**- Physics Education Technology
- **SCORE**- Science Community Representing Education
- **SOC**- Student Observation Checklist
- **SSA**- Sub-Saharan Africa
- **SSCE**- Senior School Leaving Certificate
- **TIMSS**- Trends in International Mathematics and Science Study

- **TSCE**- Tanzania Certificate of Secondary Education
- **TCU**- Tanzanian Commission for Universities
- **TVET**- Technical and Vocational Education and Training
- **UBE**- Universal Basic Education
- **UNESCO**- United Nations Educational Scientific and Cultural Organization
- **UNICEF**- United Nations Children's Fund (formerly United Nations International Children's Emergency Fund)

# CHAPTER 1

## INTRODUCTION

### 1.1 Personal Background and Motivation for the Study

My personal interest in practical physics was developed during my undergraduate studies.

Throughout most of my secondary schooling, my school was without a physics teacher. However, a few months before our final year examination, we were lucky to gain a physics teacher.

Unfortunately, we were only exposed to practical physics experiments two days before our final year practical physics examination. Interestingly, we were introduced to the likely questions the examination bodies might ask during the practical physics examination. We sat for the exam and passed even though we had a shallow knowledge in practical physics.

I was admitted into the university to study physics education in the year 2001. As is the usual practice, we were expected to carry out practical at least once in a week, even though in small groups because of the limited resources. I discovered that most of the students in the group were just like myself with limited exposure in practical physics. So, we relied on others in the group who had more practical exposure than we did. Gradually, I learned how to perform physics experiments from more experienced colleagues in my group.

Having developed an interest in practical physics in my first and second year at the university, I was posted out to a secondary school as a practicing physics teacher for three (3) months. This was part of the initial teacher education program. I was privileged to teach the Senior High School 'two' students (students who had been taught physics for two years). I started teaching the theoretical part of physics as usual and after the lessons I decided to introduce the students to practical work. I started by asking the students to list five items of physics apparatus that they knew. Interestingly, none of the 60 students in my class could list five (5) items of physics apparatus.

Immediately, I was alarmed and approached my mentoring physics teacher who had been teaching physics in the school for more than 8 years to report my findings. He laughed and said that they are not exposed to practical yet, not until they get to the final year. I realized that these students were passing through a similar scenario to myself during my secondary school days and I asked their physics teacher why the students should wait till their final year before they begin to identify physics equipment. He responded that the physics laboratory is not well equipped as most of the items of apparatus are not readily available and that, when the students are in their final year, the schools

have to go out to neighboring schools to beg for equipment to be used during the exams. I heaved a sigh of relief because I had already observed that the physics laboratory was always locked.

In the last week of my practice as a physics teacher in the school, I noticed that the laboratory was opened as the final year students were already preparing for their practical physics examination. I went into the lab and discovered that there was equipment, though limited, which could have been used to teach the students. Perhaps, engaging the students with the available equipment would have motivated them and made them believe that physics is not such an abstract subject. But, it was too late for me to develop the interest of the students in physics through a series of experiments, and it seemed to me as an opportunity missed

Because of my experience during the teaching practice, I decided to write my undergraduate thesis on *‘Utilizing Available Laboratory Facilities for Effective Teaching and Learning of Physics in Selected Secondary Schools’*. I thought it would be good to use the school where I served as a practicing physics teacher as a case study. I sought permission from the school’s head and from the physics teacher and they allowed me to gain access to their students. I decided to engage the Senior High School ‘two’ students for six (6) weeks but this time for research purpose. The study sample consisted of sixty (60) students which were divided into experimental and control groups. The experimental group was taught physics concepts accompanied by practical activities with the available resources, while the students in the control group were taught the same physics concepts without practical exposure. My findings revealed that students in the experimental group performed better than students in the control group in physics achievement tests. I was able to establish the fact that students can be engaged in practical physics even with the limited resources, and in some cases teachers can improvise instead of waiting for already made equipment.

After my first degree in 2006, I proceeded to a Master Degree in Education with specialization in physics education. In 2008, I got a teaching job as a physics teacher in a disadvantaged rural school in a South-Western state in Nigerian. Prior to my appointment, the school was without a physics teacher for more than 10 years and the students were performing poorly in external examinations. The school had been using an inexperienced school librarian to teach the students physics over the years. My first two years in the school were very successful. The school witnessed a tremendous pass rate (100%) in both internal and external examinations. In one of the staff meetings, my principal stood up to appreciate my effort in improving the students’ performance and he asked me to share the secret with other members of staff. I said “I am not better than other teachers but the only thing that makes the difference is introducing the students to practical activities at the beginning of the school term and not when the final examination is approaching”. The school

principal later urged other science teachers to always embrace practice alongside the theory sessions. Other school principals in the neighbouring schools kept calling for my help, even though their schools had physics teachers. Their schools had been having poor results and it seems as if their physics teachers were not confident in handling the practical aspect of physics. I kept asking myself the questions “Why are students performing so poorly in practical physics? Is their failure coming from the teaching, from school leadership, from government requirements or from the students themselves? Is the teaching approach used in most schools in Nigeria different from other African countries?” These were the questions that ran repeatedly through my mind.

I became delighted when the opportunity to answer these questions came in 2013. The Institute of Physics (IoP) in UK, in its bid to promote a practical approach to teaching physics in Africa, initiated a studentship on “Advancing Practical Physics in Africa’s Schools” in conjunction with the Open University in UK. I applied for the studentship and, after thorough screening and interviews, I was selected to carry out the research project which was set up to investigate the approach being taken by a number of African countries to the teaching of practical physics. This was the motivation for the study.

## **1.2 Background to the Study**

This thesis is concerned with practical physics education in African schools. Before focusing on the narrower topic, it may be helpful to outline the arguments for the importance of such activities and the need for a review. Why does practical physics teaching matter? How well is it being carried out?

Physics matters to society. Over the last three hundred years, the physical sciences, especially physics and chemistry, have contributed immensely in revolutionizing the industrial and social activities of mankind. Physics has underpinned technological advancement across the globe and is an essential ingredient in the ongoing and future technological development in the African continent (Omosewo, 1993). Because of the pivotal role of physics in technological change, development of any society requires physics knowledge and skills. In turn, this implies a high priority being given to physics education. Students are the future of a nation and scientifically literate students will be agents of development (Abdullahi, 1982). Ette (2001) has asserted the importance of physics by saying that the technological potential of a country is more accurately gauged by the quality of its physics education than any other single index.

Physics is an important subject in its own right but it also supports other subjects. Students who want to acquire higher education qualifications in the fields of engineering or medical sciences must

have a strong background knowledge of physics. So, providing secondary students with clear and standard basic physics knowledge which they can utilize in their future studies has broad value.

Science is hierarchical and scientific literacy is built progressively through secondary into tertiary levels. This literacy concerns not only scientific knowledge but also the scientific method and ways of thinking. Science depends on evidence. The value of evidence based knowledge achieved through science education is influential in society because of its practical application. For these several reasons, priority is given to science education all over the world (Malaque, Begum, Islam and Riad, 2007 cited in Banu (2011)).

Ette (2001) has argued that every science subject in secondary schools may be divided into two major aspects – practice and theory. They support each other, enabling progress in both conceptual knowledge and skills development. Neglect of either makes the subject difficult to learn. To this might now be added the computational aspect which has undergone an enormous expansion since 2001. Computers are used in a variety of ways to acquire and analyze data but one of their most important roles in the modern classroom is to carry out simulations that allow students to learn from a viewpoint that stands somewhere between the practical and the theoretical. However, this is a developing topic that will be ignored for the moment but returned to later for separate consideration.

Practical physics constitutes an important aspect of physics teaching. Ranade (2008) has suggested that the goal of providing science students with clear and standard physics content knowledge can be successfully achieved if the conceptual knowledge is supported by the inclusion of practical work. Omosewo (2006) has argued that a deeper understanding of the nature and processes of physics can be achieved through laboratory activities which encourage active participation and serve to develop critical thinking. She has argued further that physics is an inquiry oriented subject in which practical work is essential because it involves students' acquisition of a series of process skills such as; observing carefully, classifying and interpreting predicted events, designing experiments, organizing information, reporting completely and accurately, and generalizing.

Although the importance of physics and practical physics is accepted, there have been many problems in achieving high quality physics education in Africa. There are many reasons for this.

According to Okebukola (1998), the conduct of physics practicals in secondary schools in Nigeria has been hamstrung by several factors that include; defective teaching of science from junior secondary school level, poorly equipped science laboratories, dearth of qualified physics teachers, lack of standard laboratories, limited availability of practical textbooks or laboratory manuals, overcrowding

of classes and a general lack of technical laboratory skills. In addition students tend to have little interest in physics but are in attendance in obedience to the wishes of their parents or guardian.

These observations support the views of Okeke (1990). He stated that physics practical work, which is supposed to be of great assistance and a motivating factor for students, has been a major source of problems for students. There is a mass failure in practical physics because of ignorance and neglect of some basic principles in the teaching of physics practical work.

Some studies (Asikainen and Hirvonen, 2010; Ishak and Mohamed, 2008; Kasanda, 2008; and Taylor and Dana, 2003) have suggested that the main reason for students' failure to learn is the poor content knowledge of science teachers. Kasanda (2008) has suggested that well-designed teacher education programmes can help teachers to develop both subject matter knowledge and pedagogical knowledge so that they can effectively teach their students.

Asikainen and Hirvonen (2010) have broadened this analysis beyond practical physics. They believe that teachers' subject matter knowledge and pedagogical knowledge are preconditions for effectively teaching physics. Such comments echo the work of Van Driel et al. (2001). In a review study of science teaching, they argue that teachers are key to bringing about change in educational practice and outcomes. Teachers' practical knowledge consists of sets of beliefs and knowledge which have a direct impact on their actual teaching, in particular the way they explain to students the role of practical work in learning physics at secondary level. Lingbiao and Watkins (2001) come to similar conclusions in relation to education in China. They observe that the educational beliefs of teachers have significant influences on both what is taught and how teaching and learning occurs. In turn, these influence learning outcomes.

The teaching of practical physics in many secondary schools across Africa has not been prioritized adequately. Many students only do practical physics briefly and at the tail end of their course. Okeke (1999) has observed that, even at the end of the course, students lack skills in basic experimental techniques. Okeke argues that skills can only be acquired through regular exercise from the beginning. Many students are incapable of using measurement and graphical analysis in the solution of practical problems in physics. They do not give due attention to the relationship between theory and practice. As a result, they are unable to interpret numerical and graphical results in terms of the theory underlying the experiments.

Adeloye (1998) has argued that the teaching and learning of physics in African schools has been affected greatly by lack of both competent teachers and the opportunity for practical work. He reported that secondary school students found some topics in physics very difficult to understand

because such topics were not accompanied by practical work. He saw a link between the learning of content and skills.

It has been reported that interest in high school physics is decreasing, that learning motivation is declining, and that examination results are getting worse (Garwin and Ramsier, 2003; Manogue and Krane, 2003). In many school settings, little time is allotted for physics and its place as an element of the 'core' curriculum, alongside languages and mathematics, is under threat (Tesfaye and White 2012; UNESCO, 2010). Sadiq (2003), in a review of science teaching in Pakistan, argues that teaching is geared around memorization of basic concepts and their reproduction in the examinations, with students who enroll for the subject resorting to cramming definitions and formulae.

Semela (2010) has asserted that physics education has been undergoing a crisis. Enrolment in physics courses at all levels is low in many African countries. He suggests that the reasons for this include; inadequate lower-level preparation, weak mathematics background, lack of job opportunities in physics outside the teaching profession, inadequate teacher qualifications as well as teachers having poor pedagogical content knowledge.

Of course the wider international context may have contributed to this crisis. Many students consider physics as difficult, abstract and theoretical (House of Lords, 2006). The subject is considered devoid of applications in day to day life, and many students find the subject boring and not enjoyable (Hirschfeld, 2012).

These brief arguments suggest that many African schools are not offering adequate opportunities to learn practical physics, a subject that is critical to the economic and social development of the continent. The next section amplifies this conclusion and introduces the study reported in this thesis.

### **1.3 Purpose and Research Questions**

The purpose of this research is to investigate the present status of practical physics teaching and learning in secondary schools in Sub-Saharan Africa. More specifically, the study will address the following research questions:

1. What are the current aims of the practical physics curriculum in African countries?
2. What is the present status of practical physics education in African schools?
3. What are the critical factors determining success or failure in delivery of the intended curriculum?
4. How can the teaching of practical physics in African schools be improved in the short and long run?



This study is part of an attempt to improve the teaching of practical physics in Africa's schools and make the learning of physics more attractive to students. It will provide physics educators, physics curriculum planners and governments with detailed information about current practice in physics teaching and learning in Africa's schools, and will offer ways of improving the situation. It is intended that this will help in planning and formulating policies for physics education in Africa.

For practical reasons, including language familiarity, safety and educational traditions, the focus of the study is Sub Saharan Africa.

It is also hoped that the study will help in broadening the pedagogic knowledge of physics teachers and encouraging the use of practical activities in the classroom. It may also help to enlighten school principals about the type of teachers who will teach physics effectively.

Finally, the results of the study should give the necessary insights to governments and other stakeholders that will encourage them to provide necessary and adequate laboratory facilities to secondary schools in Africa.

## **1.4 Rationale for the Study**

Current research in physics teaching has indicated that current school physics teaching is not producing the kind of science literacy desired in relation to future scientific needs. There is strong evidence to suggest that many physics teachers do not always feel that the practical physics curriculum is a high priority. And when it is addressed in the classroom, it is not taught in a way that enhances and encourages student's performance (Oskamp and Schultz, 2005).

There is a great deal of anecdotal evidence that conditions in secondary schools in Africa are not satisfactory for doing practical work. Schools that have been provided with equipment do not make use of it. During the visits described in the thesis, some expensive apparatus and equipment items were found unused and deteriorating in storerooms and boxes in several of the schools. At schools where there is equipment, the school system does not allow enough time to do practical work. This is because teachers spend a lot of time doing administrative work and spend little or no time on practical work. Many of the teachers prefer to do demonstrations, which are very teacher-centered. The focus of many schools is on finishing the content syllabus rather than on effective teaching and learning. Many learners do practical work for the first time at university level without having had the proper training and background on how to do such work. Practical work, which is supposed to be of great assistance and a motivating factor for students, has been a major source of problems for students. There is a mass failure in practical physics because of ignorance and neglect of some basic

principles in the teaching of physics practical work (Okeke, 1999; Motlhabane, 2013; Institute of Physics (IoP), 2012).

There is a substantial gap between the current physics curriculum being taught in schools in Africa and the scientific and technological needs of Africa's 21<sup>st</sup> century society. The majority of secondary school teachers are not well qualified to teach physics, especially when asked to use the much preferred practical approach. Hence the classroom situation is inadequate; and both the intended and attained practical physics curriculum content is very poor in Africa.

Teachers need to be competent in practical skills in order to manage the operation of laboratory sessions and the process of learning in their classrooms, and knowledgeably lead the discussions that follow-up student's discoveries. These qualities may be lacking in many African physics teachers who have been trained and mentored using textbook and lecture methods.

All of the above observations and assertions need to be tested, refined and, if necessary changed. This is the purpose of this study.

## **1.5 Overview of the thesis**

Chapter 1 has discussed the motivation and rationale for this study.

Chapter 2 is a review of relevant existing literature on practical work in physics education specifically and science education in general. It describes the meaning of practical work and also states the various roles of practical work in science education. It then offers a general overview of the types of practical work and the various factors that inhibit effective delivery of practical work.

Demographic information and data on policies and previous practical-physics interventions are provided in Chapter 3, with a focus on the countries in which case-studies have been pursued.

Chapter 4 discusses the research methodology, which includes; the design of the research instruments, an account of the pilot study, a summary of the visit protocols and a discussion of ethical issues.

Chapters 5 and 6 provide the research data. Chapter 5 sets out quantitative data for all countries visited. Chapter 6 focusses on the qualitative results which are organized using thematic and linguistic analysis approaches.

Chapter 7 uses a thematic approach for the discussion and offers a systems led description of the factors influencing the delivery of practical work. It also provides a reflection on the reasons behind the success or failure of previous interventions.

Finally, the summary, conclusions and evidence led suggestions for future intervention strategies are presented in Chapter 8.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter aims to provide some insight into the potential role of practical work in the physics curriculum. It includes discussion of several issues:

- the meaning of practical work
- the aims of practical work in the science and physics curricula
- the various types of practical work
- the factors influencing current practices in practical work
- the potential impact of ICT in practical physics

#### **2.2 Definition of Practical Work**

According to the literature, 'practical work', 'laboratory work', 'experiment' and 'investigation' refer to similar activities but have overlapping distinct meanings (Hodson, 1998). Often they are used loosely and interchangeably. Apparently, the term 'practical work' is commonly used in the literature associated with the United Kingdom, Australia and New Zealand, whereas, the term 'laboratory work' is frequently used in North American literature and in contexts where laboratory work and experiments are used virtually as synonyms (Hodson, 1998 p .153)

In the context of science education, Millar, Lemarechel and Tiberghien (1999) define practical work as those teaching and learning activities in science that involve students at some point in handling or observing the real objects or materials they are studying. In this definition, there is no restriction on where the work is carried out. Practical work may be performed in a laboratory or outside in the field or in an ordinary classroom. Abrahams and Millar (2008) preferred to use the term 'practical work' rather than laboratory work because they claimed that science activities are not characterized by the location but by the activities of students when doing school science. Millar further asserted that science teaching naturally involves more than asserting facts. It includes showing learners how things happen and putting them into situations where they can observe for themselves.

Practical work can be regarded as any learning activity in science that encompass learning by experience (Hodson, 1998). This is most easily understood when students have first-hand experience

in seeing, feeling and handling objects and organisms for themselves. For example, Hodson mentions the students' experiences of seeing a bright light from burning magnesium, feeling the forces of magnetic repulsion and attraction; seeing the bending of light through a glass prism; seeing microscopic organisms using microscopes and connecting simple electric circuits. He claimed that most of the phenomena that are addressed in school science do not usually occur in everyday life. Hence, providing an opportunity for students to directly experience these phenomena and events helps them to have a background framework to understand the scientific concepts associated with their experiences.

Bell (2004) stated that practical work is not just about experiencing phenomena but also about thinking — a cognitive activity. According to Bell, practical work should be considered as a thinking activity in which each participant constructs understandings from experiences rather than being solely the domain of manipulative work with the hands (Bell, 2004, p 169). Hence, practical work is seen as including both the handling of science equipment and the linked thinking processes.

Hodson (1998) saw learning by experience as a process that encompasses students both experiencing the procedural understanding of making meaning and constructing conceptual understanding. Conceptual understanding deals with the factual knowledge, concepts, laws and theories of science while procedural understanding has been used to describe the understanding of ideals about evidence. Such ideals underpin an awareness of how to proceed effectively (Gluesser, Gott, Roberts and Cooper, 2009, p.597). Hodson (1998) did not limit 'learning by experience' to direct physical engagement. He suggested that practical work should utilize a wide range of other active learning experiences such as the use of historical case studies, simulations and dramatic reconstructions, role playing and debating, computer based activities and thought experiments (p.149). Such activities provide opportunities for students to experience and to rationalize the messiness of science processes, as well as to understand the social events behind the phenomena and the construction of scientific knowledge. This general view was also expressed by Gott and Duggan (2007).

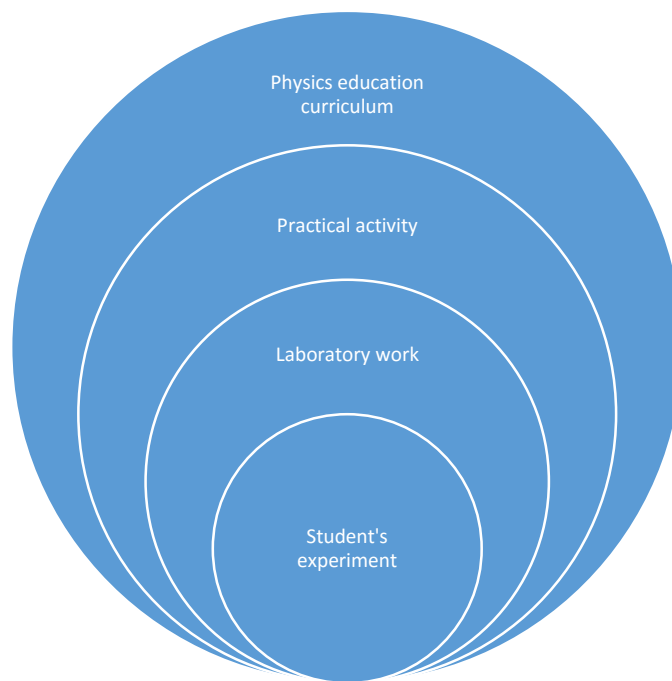
In 2009, the UK based Science Community Representing Education SCORE ( a collaboration of leading science organizations) defined practical work to be any science teaching and learning activities that involve students, working individually or in small groups, manipulating or observing real objects and materials as opposed to the virtual world.

Woodley (2009) defined practical work as a hands-on learning experience that stimulates thinking about the natural world. He further identified possible practical work as being of two kinds.

1. Core activities, investigations, laboratory procedures and techniques, and fieldwork, all of which support the development of practical skills and help to shape students' understanding of scientific concepts and phenomenon.
2. Directly related activities, i.e. teacher demonstrations, the experiencing of phenomena, designing and planning investigations, analyzing results and carrying out data analysis using ICT. Such activities are closely related to the core activities and are either a key component of an investigation or provide valuable first hand experiences for students.

The Handbook on Research in Science Education (Abell and Lederman, 2007) provides what they call a 'classical definition' of laboratory activities. It describes laboratory activities as learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world. Examples include: aerial photographs to examine lunar and earth geographic features; spectra to examine the nature of stars and atmospheres; and sonar images to examine living systems. (Lunetta et al, 2007, p.394). Although described as 'classical' this definition allows for the indirect observations that are an increasing part of contemporary science.

Meester and Kirscher (1995) cited in Vilaythong (2011) have provided an interesting analysis of the interrelationships between the various types of practical activities. Laboratory work contrives learning experiences in which students interact with materials to check and observe phenomena in a laboratory classroom. They define a practical activity as a didactic method for learning and practicing all activities involved in carrying out practical inquiry relevant to one's profession. This identification with the acquisition of professional skills is useful. It implies that the scope of practical activities should change with evolving professional skills. According to Meester and Kirscher the interrelationship between practical activities, laboratory work, and student experimentation is that they represent a series of subsets that start with the physics education curriculum and work down to student experiments. These relationships are shown in Figure 1.



**Figure 2.1:** Interrelationship between experiment, laboratory work, and practical activity in the physics curriculum. Adapted from Vilaythong (2011)

The conceptual scope of practical work investigated in this thesis is essentially the same as suggested by Millar, Le Marechal and Tiberghien (1999). Practical work is any teaching and learning activity that involves at some point the students in observing or manipulating real objects and materials. Their concept, as quoted earlier in this chapter, embraces laboratory activities done by students and teacher demonstrations. Such understanding reflects the traditional interpretation of practical work in physics education in Africa. It includes students handling equipment and materials by themselves or students watching the teacher handle equipment and materials.

In summary 'practical work' is an overarching term which encompasses activities that provide students with the opportunity to learn by experience. Practical work in secondary school physics usually takes the form of laboratory experiences, demonstrations, fieldwork, investigations and excursions. Teacher innovativeness and creativity could also introduce novel modes of practical works. However, terms such as 'laboratory work', 'experiments', and 'investigations' are used at times to emphasize particular meanings and contexts. Whatever term is used, the underlying recognition in this study is that such activities provide opportunities for students to have a learning experience relevant to the practice of physics.

## **2.3 Aims of Practical Work**

Science is a complex technical and social activity with many facets. Its nature and purposes may be debated at length. For this thesis the simple and essentially neutral understanding of the aim of science provided recently by Millar (2010) is adequate. Millar says that the aim of science is to increase our understanding of the natural world, what it is made of, and how it works. Millar asserts further that science teaching involves showing learners certain things (objects, processes, phenomena), or putting them into situations where they can see such things for themselves. The need for exposure follows naturally from science's focus on the physical world. Simply telling students about the world without linking such telling to experiences is unlikely to feel appropriate or to be effective. In countries with a long tradition of laboratory-based science teaching at school level, practical work is seen by many teachers as an essential aspect of their everyday practice. It is often claimed that practical work leads to better learning in that we are more likely to understand and remember things we have done than things we have merely been told. It is also considered by many teachers, and by other with an interest in science education (House of Lords Science and Technology Committee, 2006; SCORE, 2008), to be the key to catching and holding learners' interest in science and encouraging them to pursue the subject further.

Millar's assertion about the need to include practical work in the science curriculum is supported by the work of many educational researchers who have attempted to break down the rationale for practical work. Sharpe (2012) has reviewed a range of early contributions.

### **2.3.1 Large Scale UK Based Studies**

Over fifty years ago, Kerr (1963) investigated the reasons offered within schools for carrying out practical work in science. The study examined 151 schools in England and Wales. All the schools were selective (grammar) schools of which 56% were boys' schools, 26% girls' schools and 18% were co-educational. There were 701 science teachers in the study (218 chemistry, 258 physics and 225 biology). An open-ended survey was used to explore the nature, purpose, and assessment of practical work according to teachers. The responses were summarised in ten aims which teachers were invited to rank in importance for different schools levels (Table 1, column 2).



**Table 2.1:** The overall ranking of Kerr's ten aims in the study for each science at sixth form level (adapted from Kerr (1963, p.27)).

Kerr's ten aims of practical work with overall ranking		Teachers' ranking for 6 <sup>th</sup> Forms		
		Physics	Chemistry	Biology
1	To encourage accurate observation and careful recording	1	1	1
2	To promote simple, common-sense, scientific methods of thought.	4	4	4
3	To develop manipulative skills	6	5	5
4	To gain training in problem solving	8	7	9
5	To fit the requirements of practical examinations	10	8	8
6	To elucidate the theoretical work so as to aid comprehension	2	2	2
7	To verify facts and principles already taught	5	6	7
8	To be an integral part of the process of finding facts by investigation and arriving at principles	3	3	3
9	To arouse and maintain interest in the subject	9	10	10
10	To make biological, chemical and physical phenomena more real through actual experience	7	9	6

In physics, the overall ranking of the ten aims of practical work shows the highest rank given to improving investigative skills, with the process of meeting the needs of practical examinations coming last; something that should not indeed 'influence the practical work, but we know it does' (Kerr, 1963, p.30)

The ten aims were widely recognised by teachers across levels but there was some divergence in the details. For the lower school years, Aim 9 – 'to arouse and maintain interest in the subject' – had the highest overall ranking. In contrast, for Year 12 and 13, Aim 1 – 'to encourage accurate observation and careful recording' – was ranked highest.

In his study Kerr commented on the discrepancy between the stated views of teachers and their practice. Not surprisingly, the practice implied the ranking of the aims was subject to the usual constraints of professional life. In Kerr's words, 'tradition and convenience perpetuated outmoded methods'.

A follow up study by Thompson (1975) demonstrated limited agreement between teachers of different subjects at sixth form level (Years 12-13). Thompson used a nation-wide survey similar to the Kerr study, with responses from 221 physics, 220 chemistry and 214 biology sixth form teachers. Thompson used twenty aims but, for the purposes of comparison, these have been collapsed into

Kerr's original ten. The findings reported substantial changes since the Kerr report in 1963 with regards to the purposes of practical work in the sixth form. The Thompson study found that the aims relating to teaching skills of observation and description remained of primary importance but some other rankings were changed. Most notably, the sixth form teachers saw the use of practical to aid comprehension as being more important and gave less value to motivation and tangibility.

The most noticeable increases in the ranking of the aims related to practice problems, arousing and maintaining interest, promoting logical thinking and making phenomena tangible. Thompson commented that practical work was being seen as *'much more as a distinct activity, no longer concerned predominantly with the transmission of specific syllabus content, as illustrated by the considerable drop in position of Aim 10'* (Thompson 1975, p.72).

In addition to the teacher data, Kerr (1963) analysed 624 student questionnaires and found major discrepancies from the views of their teachers. Few students shared the teachers' understanding of the role and value of the practical work, e.g. in developing scientific thinking or behaviour. Kerr's report suggested that teachers should try to be more explicit with students about the intended learning outcomes and the expectations of practical work. Several authors have commented on or affirmed the continuing validity of Kerr's findings (Abrahams and Saglem, 2010; Jenkins, 1998; Wellington, 2005)

Research of teacher opinions on the aims of science practical work was continued by Beatty and Woolnough (1982) who used Kerr's ten aims and the additional ten from the study of Thompson (1975). They were concerned with lower secondary schools in the UK (Years 7-9). The methodology used was a questionnaire with 238 items in four sections covering: background information; the science teaching system at the school; the type and frequency of practical work conducted; and the ranking of the twenty aims. The respondents were 56% comprehensive schools, 10% secondary moderns, 6% grammar schools, 10% middle schools, and 8% independent schools (Beatty and Woolnough, 1982). This reflects the composition of the school system at that time. The overall ranking of aims results in the Beatty and Woolnough study can be seen in Table 2.2.

**Table 2.2:** Overall rank order of the twenty aims (Beatty and Woolnough, 1982)

Aim	Aim (in abbreviated form)	Ranking
1	*To encourage accurate observation and description	7
2	*To arouse and maintain interest	12
3	*To promote a logical, reasoning methods of thought	6
4	*To make phenomena more real through experience	2
5	To be able to comprehend and carry out instructions	9
6	*To develop specific manipulative skills	16
7	To develop certain disciplined attitudes	15
8	To develop an ability to communicate	13
9	*To practice seeing problems and seeking ways to solve them	4
10	To help remember facts and principles	3
11	*For finding facts and arriving at new principles	8
12	To develop a critical attitude	18
13	To develop an ability to co-operate	14
14	To develop self-reliance	11
15	To give experience in standard techniques	19
16	As a creative activity	1
17	*To elucidate theoretical work as an aid to comprehension	10
18	*To verify facts and principles already taught	17
19	To indicate the industrial aspects of science	5
20	*To prepare the student for practical examinations	20
*Aims used by Kerr in 1963		

In discussing their data, Beatty and Woulnough (1982) commented that *'Perhaps the most striking and surprising overall result was the similarity of response given by different 'types' of teachers teaching in quite different types of situations. .... One might have expected that, say, a physicist might have had different aims from a biologist, teachers in boys' schools different from coeducational schools, teachers in independent schools different ..... but the evidence did not suggest such differences.'* They also concluded that there was no evidence that teacher opinions had changed dramatically since Kerr's study of 1963 in spite of the major curriculum changes that had taken place in the intervening period. However, they did offer the tentative view that, for this age

group (Years 8 and 9), teachers had increased their concentration on skills development and reduced their focus on the use of practical as an aid to the understanding of theory.

The proportion of class time that teachers devoted to practical work was somewhat variable but the median was in the 40% to 60% band. This is a surprisingly high figure and it does show that teachers regard practical activities as valuable, though it should be borne in mind that teacher led demonstrations are included within this figure.

Beatty and Woolnough (1982) expressed the same caution as Kerr (1963) about the validity of their findings. They concluded that the findings *'may not necessarily reflect what is taking place in the laboratory and the question which must be posed is 'are they doing it? ..... only by closer scrutiny of the work in schools can the nature of actual practice be determined'*. They suggested that an investigation requiring the researcher to encounter the reality of the laboratory directly would make it possible to *'extend or refute the insights revealed in this survey'* (pages 29-30).

There are obvious problems with direct comparisons of the three large scale studies reported above (Kerr, 1963; Thompson, 1975; Beatty and Woolnough, 1982). They cover different types of schools and use overlapping but different lists of possible aims. Nevertheless, the various findings indicate that the rhetoric, views and ranking regarding practical work did not differ significantly across the studies. Indeed, the results showed conformity of opinion regarding the ranking of aims in order of importance for practical work (Beatty and Woolnough, 1982).

In addition to the problem of direct comparison, there are other methodological issues with the three studies. As already acknowledged by the authors, the studies were questionnaire based and did not investigate or observe the implementation of practical work within the schools (Abrahams and Millar, 2008). According to Yung (2006) and Sharpe (2012), the method used by the Thompson and Kerr studies utilised a reductionist approach based on a previously devised set of aims and *'no attention was given to individuality and variation due to differences in local context'*. This meant that the study might not reflect what the teachers actually did or reveal teachers' actual attitudes to practical work. A similar objection was made by Justi and Gilbert (2005). They argued that questionnaire based studies alone are limited in value – they are not likely to highlight areas outside the parameters of the questionnaire. Instead they argued that the use of a variety of methods, including open-ended instruments, is required to gain a better understanding of the reality of science education. Others have supported this position and argued for methodologies involving at least three data collection techniques (see for example, Briggs and Coleman, 2007; Cohen, Manion and Morrison, 2000). Of course, practical constraints may limit the scope of any study but the issue of balancing closed convenience with open-ended flexibility is important.

Another concern was about the timing of the studies (Gott and Duggan, 1995, p.18). Thompson's study was carried out at a time when there was shared concern in the UK educational establishment that practical work was recipe based and was too focused on verifying theory and illustrating concepts. It was 'routine and repetitive'. It is possible that this influenced both the commissioning of the study and may have affected the respondents. Once again, the reality of practice may not have been seen (Abrahams and Saglem 2010; Bennett, 2005). However, the Thompson study was very influential in that it helped to provoke the development of a radically different discovery-led curriculum – the Nuffield approach (Adey, 2001).

Similar issues of timing may have affected the Beatty and Woolnough (1982) data. By that time, there was a degree of disillusion with the Nuffield approach and increasing interest in the so-called 'processes and skills' approach which focused in the acquisition of the capabilities of contemporary scientists (Gott and Duggan 1995; Screen, 1988).

A fairly recent UK Government commissioned report has shown that science teacher views on the roles of practical work have evolved but not changed radically (SCORE, 2008). In a balanced survey of 1100 science teachers (24% physicists), the teachers were asked to identify the three most important of nine possible aims. The secondary school teachers ranked them as follows (1 is highest);

1. to teach skills (64% of respondents)
2. to encourage scientific enquiry e.g. asking questions
3. to develop an understanding of investigative processes
4. to motivate pupils
5. to provide enjoyment and satisfaction for pupils
6. to teach concepts
7. to provide familiar and useful contexts for science
8. to simulate how scientists work
9. to encourage group/team work (15% of respondents).

It can be seen that teachers support multiple aims. Skills are regarded as important but so too are the encouragement of pupils, conceptual support and the development of professional attitudes and capabilities.

In spite of the many objections to the large scale empirical studies described above, they still provide a useful underpinning to any analysis of the aims of practical science.

### 2.3.2 Other Research on the Aims of Practical Work

Any discussion of the aims of practical science is a fraught process. The nuance of words and phrases may not be shared by the deviser of a list and the respondent, or even by two different respondents. Such issues may be magnified when the social and linguistic contexts differ markedly, e.g. between the UK and Sub Saharan Africa. In addition, the respondent may find it difficult to distinguish between items on a long and elaborate list of options. For example, it might be argued that there is an overlap between the aim 'to elucidate theoretical work as an aid to comprehension' and the aim 'to verify facts and principles already taught', two of the items in Table 2.2.

Several authors have constructed shorter synoptic lists of the purposes of practical work. In a review that covered the research basis for educational practice, Shulman and Tamir (1973) suggested the following aims (edited for brevity):

1. to arouse and maintain interest, attitude, satisfaction, open-mindedness and curiosity in science
2. to develop creative thinking and problem-solving ability
3. to promote aspects of scientific method (e.g. formulating hypotheses and making assumptions)
4. to develop conceptual understanding and intellectual ability
5. to develop practical abilities (e.g. designing and executing investigations, observations, recording data, and interpreting results).

Shulman and Tamir (1973) expressed scepticism about the empirical evidence that such aims were being met. Anderson (1976) constructed a list with similar elements:

1. to foster knowledge of human enterprise of science so as to enhance student intellectual and aesthetic understanding
2. to foster science inquiry skills that can transfer to other spheres of problem-solving
3. to help the student appreciate and in part emulate the role of the scientist
4. to help the student grow both in appreciation of the orderliness of scientific knowledge and also in understanding the tentative nature of scientific theories and models.

These typologies are not the same but have common themes, such as student motivation, improvement of scientific skills and the promotion of the scientific culture. However, by 1982, Hofstein and Lunetta suggested that the purposes, as stated above were rather similar to the purposes of science as a whole and that distinct reasons for practical work were needed, especially at a time when there had been a shift away from student-led work. This change, which provided less time and experience in the science laboratory, was driven by examination requirements (Gott and

Duggan, 1995). Hofstein and Lunetta (1982) suggested that suitable laboratory activities could have wider purposes, including the effective development and promotion of logic, inquiry and skills for problem-solving. However, the extent to which such skills and inquiry could be learnt just as effectively through other pedagogic methods has been raised (Clackson and Wright, 1992).

In 1990, Hodson reported that the views of teachers were consistent with five possible aims and justifications of practical work. These were:

1. to motivate by stimulating interest and enjoyment
2. to teach laboratory skills
3. to enhance the learning of scientific knowledge
4. to give insight into scientific method and develop expertise in using it
5. to develop certain 'scientific attitudes', such as open-mindedness, objectivity and willingness to suspend judgement.

In a further exploration of practical work, Hodson (1998) points out that the teachers often see practical work as a means of obtaining factual information and data from which conclusions are later drawn. He goes further by stating that: *'it has usually been assumed that these data are pure and 'unaffected' by students' existing ideas and, therefore, students have not usually been involved in the design and planning of experimental investigations'* (p. 146). This kind of teaching approach does not contribute to students learning how to construct their personal meaning of the scientific knowledge in a meaningful way in that it fails to engage them in the thinking that precedes an experimental investigation.

However Hodson was unconvinced about teacher success in meeting these aims. In his 1990 paper he commented that *'theoretical arguments and research evidence have reinforced the view that practical work in school science as presently organised is largely unproductive and patently unable to justify the often extravagant claims made for it'*. He has repeated these views in more recent publications (Hodson, 1996; Hodson 2009).

In his book 'Improving secondary science teaching' Parkinson (2004) set out aims derived from reports in the period 1947 to 2004. He included:

1. to encourage observation and description
2. to make phenomena more real
3. to arouse and maintain interest
4. to promote logical and reasoning method of thought
5. to motivate and promote interest to do science

6. to teach the skills to make accurate observations
7. to teach manipulative skills
8. to promote logical thinking
9. to understand or accept theory
10. to develop communication skills
11. to learn through group discussion
12. to work as a team.

Watson (2000) was more synoptic. He contended that, despite changes in the kinds of practical work done over time, four main aims can be identified, namely the first four of the list above, i.e.

1. to encourage observation and description
2. to make phenomena more real
3. to arouse and maintain interest
4. to promote logical and reasoning method of thought.

A somewhat different way of examining the role of practical work is to focus on the affective level. It has been argued that practical work creates motivation and interest for learning physics when tacit knowledge of scientific phenomena can be gained (Collins, 2001). Millar (1998) has argued that practical work should be viewed as an important means of allowing the physics learner to reconcile and link the physical world with its physics description. Millar stated further that properly designed practical work has a broader value - from the early secondary school period it can help in the development of critical thinking skills. If students are allowed to participate and be put at the centre of learning, they will be motivated to know more about what the subject can offer.

However, the reality of practice is that most school experiments are dull and uninformative, and that most learners don't recognise their purposes (Hodson, 1990; Hodson, 1991). Hodson claims that practical work practised in many schools and countries is ill-conceived confused, and unproductive and has not yet been successful in achieving the goals it is purported to achieved. Millar and Abraham (2009) have stated that although students find practical work enjoyable, they learn little from it. They also say that a few weeks after carrying out a practical task, most students recall only superficial details and are unable to say what they learned from it. Osborne (1998) also argued that practical work plays a very limited role in learning science and that it has little educational value.

The many contributions that are summarised above identify broadly similar aims. However, there is little clarity on how they are reflected in practice. According to the Science Community Representing Education (SCORE, 2008), the true purpose of practical work is still unclear. This confusion may lead to different approaches to practical work and to different learning outcomes (Millar, 1998). Several



educational researchers have argued that the lack of clarity of aims led to a lack of confidence in developing effective pedagogies with effects on learning (e.g. Clackson and Wright, 1992; Hodson, 1990).

### **2.3.3 Non UK Studies into the Aims of Practical Work**

The main though not exclusive emphasis in the preceding discussion was on studies from and about the UK. This is not unreasonable as the UK tradition of practical work is well developed and the approaches have influenced science teaching in much of Sub-Saharan Africa.

In a 1998 study, Woolnough (1998) asserted that the United Kingdom has a stronger emphasis on practical work than the large majority of other countries. This view was supported by Woodley (2009) who found that teachers in England adopt a hands-on approach to teaching and that their students are spending more lesson time on practical work than their international counterparts. According to a UK House of Commons report (2002a), Hong Kong and Thailand were the only countries at that time where students spent more time undertaking practical work than England. The most exhaustive analyses of classroom practice in science are the Trends in International Mathematics and Science Studies (TIMSS) published by the National Foundation for Educational Research (NFER). Sturman et al's commentary on the 2007 TIMSS study notes that 'England's grade 8 science pupils are more likely to spend their lesson time doing practical science activities than many of their international counterparts (Sturman et al, 2008). The report shows that 58% of science teachers in England believed that their students spent half or more of classroom time carrying out experiments or investigations. The average figure across the 36 participating countries in the study was 36%. Countries with a higher emphasis on practical work were Armenia, Taiwan, Iran and Japan. There were no Sub-Saharan African countries in the study. Unfortunately the equivalent TIMSS study in 2011 did not provide directly comparable data and it is not possible to assess recent trends in the allocation of UK classroom time.

In a comparative study Swain *et al.* (1999) examined teachers' attitudes to practical work in science education in Egypt, Korea and the UK. Teachers were asked to list the most important five aims from the twenty aims used in Beatty and Woolnough (1982). The results revealed that the three groups of science teachers regarded the importance of the aims of practical work to teach science differently but that all groups *'express a common attitude to the aims of practical work that reflect an acknowledgement of the methods by which scientists make new knowledge'*. Overall, both the Korean and Egyptian teachers show a strong tendency towards a more positivistic approach to science compared with their counterpart UK teachers, who appear to be offering a view that is more investigation oriented. The Korean teachers were content focused whilst the Egyptian teachers gave

lower ratings to aims such as 'making phenomena more real' or 'arousing and maintaining interest'. According to Swain et al. (1999), the value of such aims might only become clear with practice. Swain et al's general conclusion was that local practice and discourse are the central determinants of the opinions of teachers.

Hofstein and Lunetta (2003) pointed out that, among several aims of practical work mentioned in the literature, there is a lack of teacher awareness of how laboratory activities can be the main vehicle in enabling students to achieve science knowledge. Many teachers do not know how students can be engaged in laboratory activities in such a way that the development of science concepts is promoted. In addition, the same authors point out that many teachers do not understand that helping students understand how scientific knowledge is developed and used in a scientific community is an especially important goal of laboratory activities.

In this discussion of the aims of practical work, two studies conducted in the African context should be mentioned. These are from Ghebremariam (2000) in physics and Fessehatsion (2003) in chemistry. Both studies were conducted in Eritrea with secondary school teachers. In the Ghebremariam (2000) study, the physics teachers from five selected secondary schools rated the aims of practical work in order of importance as follows:

1. to verify facts and principles already taught or to determine cause and effect
2. to make physical phenomenon more real through actual experience
3. to encourage accurate observation and careful recording
4. to arouse and maintain interest in the subject
5. to promote the understanding of scientific methods or techniques.

In Fessehatsion's (2003) study, the chemistry teachers rated the most important aims as follows:

1. to verify facts and principles already taught
2. to make biological, chemical and physical phenomena more real through actual experience
3. to arouse and maintain interest in the subject
4. to give training in problem-solving
5. to develop manipulative skills.

However, most aims listed in the studies of Ghebremariam (2000) and Fessehatsion (2003) above which were used for physics and chemistry look very similar to the general aims of practical science as mentioned in the studies of Beatty and Woolnough (1982) and may not be suitable for practical

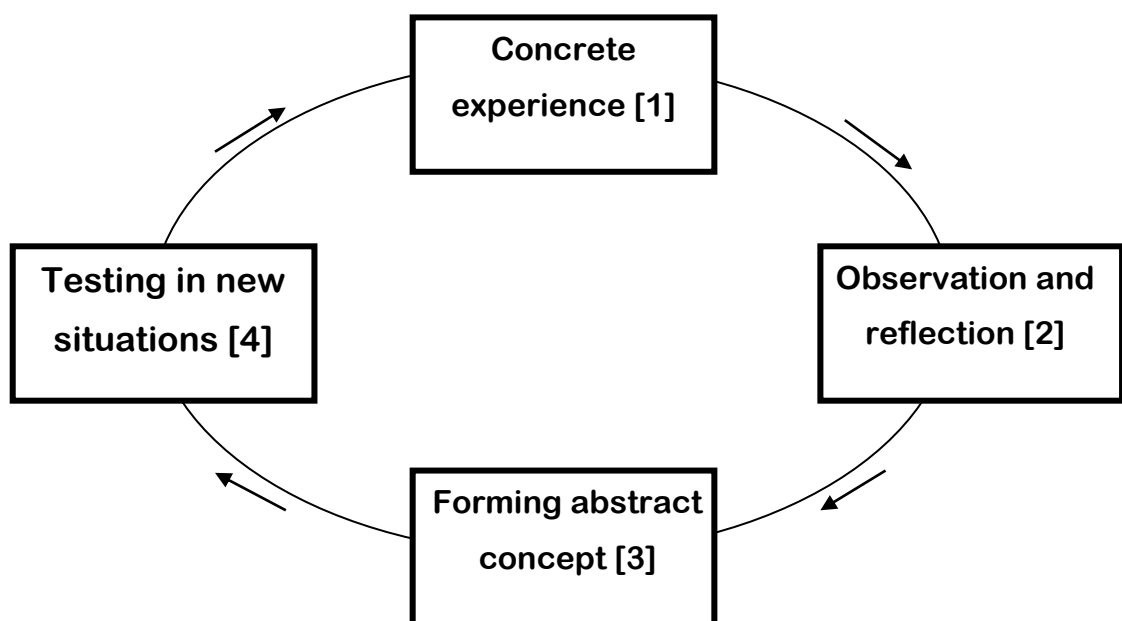
physics as it deals with precision of measurement and development of skills in the design of instruments.

Manjit Sidhu et al (2003), suggested the following aims for practical work in physics:

1. developing familiarity with apparatus, instruments and equipment
2. acquiring manipulative skills by the learners
3. developing student expertise for reading all manner of scales.

They stressed further that the observations made and results obtained are used to gain understanding of physics concepts, and that science process skills necessary for the world of work are systematically developed. These comments were made in the context of the application of IT and may have been influenced by this background.

In an interesting 'reflection', Motlhabane (2013) discussed the role and viability of effective practice in disadvantaged rural schools in the South African context. He asserts the connection between 'hands on' and 'minds on' and suggests the explanatory value of a practical work focused version of the Kolb experiential learning cycle (McMahon, 2006; Knowles, Holton and Swanson, 2005 (p. 198))



**Figure 2.2:** Kolb's experiential learning framework  
Source: Knowles, Holton and Swanson (2005: 198)

Similar observations are made by Muhasia et al. (2011) following an empirical study of girls studying physics in Kenya. The authors argued that learner led practical work increased interest and improved outcomes in both skills and wider outcomes.

Having examined the literature on the aims of practical science, and noting that there are few papers that are specific to physics as opposed to science in general, this study will propose five aims for practical work in physics. These aims are drafted so as to recognise that physics has an emphasis on metrological precision and mathematical analysis. The aims are as follows:

- to develop skills in the design of experiments and investigations
- to encourage skills of working together in a scientific context
- to provide a context for the development of mathematical skills
- to make new observations about the natural world
- to encourage the development of skills in the design of instruments.

The first and last of these are related but distinct. For clarity, *designing experiments and investigations* means the devising of systematic methods for planning, conducting, analysing and interpreting experiments. On the other hand, *designing instruments* is the process of fabricating, and assembling scientific equipment.

As explained in Chapter 4, teachers will be asked to rank these aims in order of importance and they will also have the opportunity to add any important aim that is not in the list above.

## **2.4 Types of Practical Work**

The previous section summarised work on the purposes of practical work in science. In this section, the focus is on the types of practical work that are used to achieve those purposes.

Wellington (1994) considers that different types of practical activities are appropriate for different aims of practical work. This view is not controversial. Wellington points out that there are at least six ways of organizing and carrying out practical work in the usual school situation: (i) demonstrations (used to illustrate events or phenomena); (ii) class experiments (small group activities in which the groups perform similar tasks); (iii) circus of experiments (small groups on different activities in a 'carousel', often spread over chunks of a lesson or over several lessons); (iv) simulations and role-play (activities based on real events); (v) investigations; and (vi) problem-solving. It may be noted that this list includes both teacher and learner centric approaches.

Parkinson (1994) asserted that the type of practical task varies from classroom to classroom. He set out four types of practical work;

- learning basic skills - pupils will develop these skills as they carry out practical activities
- illustrating a theory or concept - pupils will have a better understanding of a scientific idea if they have observed an experiment to illustrate that idea
- providing a theory - pupils are required to generate the 'correct' scientific answer by carrying out experiments
- Investigative work - pupils are required to plan their own experiments, carry them out, and draw their own conclusions from the experiments.

Woolnough (1991) claimed that practical science consists of three types of activity; namely investigation, exercise and experiences. This typology builds on previous work (Woolnough and Allsop, 1985). According to Woolnough (1991) investigation constitutes the heart of the scientific activity. He goes further in asserting that *'the process of planning, performing, interpreting and communicating, with its continual modification through feedback, is fundamental to the way scientists work* (p. 186). The second type of activity, exercise, is important when the scientific activity requires the development of a particular skill. The third type, experience, is designed specifically to give the students a feel for the phenomena under investigation. Experience allows the student to build up personal experiences and the tacit knowledge important to form the basis for the subsequent action and to develop understanding as links are formed during investigations. However Woolnough and Allsop (1985) in their discussion about the varieties and aims of practical work pointed out that practical work is abused when laboratory activities do not match the intended aims.

Tomlinson (1991), in discussing the methods used to achieve the aims of practical work, added one type of practical work to the four major types set out by Parkinson. His formulation is slightly different, i.e. the list includes: (i) standard exercises; (ii) discovery experiments; (iii) demonstrations; (iv) projects; and (v) 'book' experiments (his addition). In adding the fifth type, Tomlinson makes the following argument *'many experiments cannot be performed as practical exercises or as demonstrations for a variety of reasons such as the lack of time, the excessive cost of apparatus, possible dangers of the experiment or the time it takes to complete the work'* (p. 9). He saw this kind of practical work as being an important technique as it can encourage critical thinking and provide students with an opportunity to be exposed to scientific papers. In this way, their analytical skills in considering the results of experiments and observations during investigations can be improved.

Gott and Dugan (1995) emphasize that several attempts have been made to classify the kinds of practical in order to define their respective roles. Gott et al. (1998) summarize the types of practical work into five broad categories (Table 2.3).

**Table 2.3:** summary of the different types of practical work suggested by Gott et al. (1998).

Types of practical work	Aims of practical work
<b>Skills</b>	To acquire a particular skill
<b>Observation</b>	To provide opportunities for pupils to use their conceptual framework in relating real object and events to scientific ideas
<b>Enquiry</b>	To discover or acquire a concept, law or principle
<b>Illustration</b>	To prove or verify a particular concept, law or principle
<b>Investigation</b>	To provide opportunities for pupils to use concepts, cognitive processes and skills to solve problems

The types of practical work developed by Gott *et al.* (1998) and described by Gott and Dugan (1995) were elaborated by Bekalo and Welford (1999). In their survey of the secondary pre-service teacher education in Ethiopia they identified:

- **Basic skills:** measurement, selecting and use of appropriate instruments following instructions, and the constructions of tables, charts and graphs from data generated from students' experiments or drawn from other sources
- **Observation:** observing similarities or differences and changes between objects and/or events, generating classifications of patterns
- **Illustration:** showing (often through teachers' demonstrations) given phenomena, concepts, laws or principles in action
- **Enquiry:** 'discovery', a concept in a series of more or less structured activities, usually designed for students to carry out investigations following instructions to find out, confirm or 'see' a concept in action
- **Investigation:** designing and carrying out an entire investigation, which includes examining the data of the investigation and drawing conclusions from them.

However, Gott and Dugan (1995) cautioned that, in order for the various types of practical work listed by several authors to be implemented professionally, it is important that teachers are precise about the required learning outcomes of the lesson and decide whether practical work is the best way of achieving those goals.

## 2.5 Barriers to Practical Work

Having examined the various types of practical work, this section will look at some of the obstacles to progress in the teaching and learning of practical work according to researchers in the field of science education.

Current practice in practical work has been influenced by many factors, for instance, the interrelationship between practical work and the wider curriculum, resources availability, assessment, classroom environment, teacher preparedness, laboratory instruction and teaching effectiveness (Calloids et al, 1997 cited in Cossa, 2007).

According to Crawford (2000), teachers' attitudes, knowledge, skills, and behaviours are factors that affect the attainment of the laboratory objectives. Teaching in the laboratory requires a high level of pedagogic skill, technical proficiency and subject matter knowledge, as well as specific personal attitudes and a readiness for risk taking. Although there are many factors that influence student learning during practical work, the teacher is regarded as being the single factor that makes the greatest impact. Several studies that have attempted to illustrate the way practical work is currently conducted in schools have unearthed various weakness and inadequacies. A description by Lazarowitz and Tamir, (1994) summarised the general findings as follows:

*'Although teachers appeared to value laboratory activities, they did not implement them in the manner that facilitated the types of learning that was planned.... In most cases the laboratory investigation is intended to confirm something that has already been dealt with in an expository type lesson. Students are usually required to follow a recipe in order to arrive at a predetermined conclusion. As a consequence the cognitive demand of laboratory work tends to be low (p.115)'.*

Lyons (2006) states that science teachers do not have time to do practical activities due to the overloaded curriculum. He states further that the overloaded science curriculum compels teachers to focus more on completing the syllabus than on the pedagogy of science teaching. Osborne and Collins (2001) believe that this is the reason why teachers use transmissive pedagogy. Although Ranade (2008) does not mention overload of the science curriculum as a reason that compels teachers to use transmissive pedagogy, she does mention this as a burden on school science students. Thair and Treagust (1999) and Halai (2008) also mention the overloaded science curriculum as one of the commonly reported constraints in science education.

Although the required science curricula of developing countries recommend the use of practical activities, a number of constraints prevent the effective implementation of these in classrooms (Thair and Treagust, 1999). Among the existing constraints, those that are commonly suggested to

be important include: (1) limited facilities and low maintenance standards, (2) lack of laboratory assistants requiring teachers to spend lengthy periods preparing experiments, and (3) the lack of teachers' knowledge, skills, and confidence (Thair and Treagust, 1999; Cook and Taylor, 1994). These barriers restrict the amount of practical work that can be performed. Although science curricula may be well-designed, science teachers have to depend on lecture methods in their teaching. In effect, students follow rote learning (Ranade, 2008). The findings of the study conducted by Nivalainen et al. (2010) also show that practical work in physics is challenged by the limitations of the laboratory facilities, teachers' insufficient knowledge of physics, problems in understanding instructional approaches, and general lack of organisation of practical work.

Process skills not being examined in national examinations is another weakness of science education in many developing countries (Cook and Taylor, 1994). Some have argued that this is the most crucial factor to be addressed by the education system of some developing countries (Thair and Treagust, 1999).

Halai (2008) states that there is a significant shortage of science teachers in schools and that the situation is much worse in rural areas. She also mentions that there are teachers who never studied science in school yet teach science subjects because of the shortage of science teachers. Kasanda (2008) notes that there is a lack of science teachers, even in some highly developed countries, such as Canada, USA, the UK, and Sweden. Halai (2008) states that the shortage of science teachers creates extra workload for the teachers which compels them to teach a large number of classes with a large number of students, and that is why they tend to focus on covering the syllabi for the examinations. Ranade (2008) mentions that large class size is a hindrance for the teachers trying to use activity methods and it leads them to the teaching of science through the over use of lecture methods.

Researchers have proposed some strategies to overcome the existing limitations and promote the implementation of meaningful practical activities in physics. Thair and Treagust (1999) state that the expected benefits of practical work will remain uncertain if science achievement tests neglect to measure the skills developed during practical activities. They propose that physics curricula in developing countries should be modified to; remove obvious colonial distortions; increase emphasis on teaching using practical activities; and reduce emphasis on factual recall. Nivalainen et al. (2010) suggest that teacher education programmes should provide physics teachers with well-designed courses in practical work, which aim to familiarise the teachers with practical work and to help them understand its purpose. This is especially important in education systems where the teacher trainees



have not experienced much practical work themselves and, therefore, may not have experienced the benefits of practical work.

Thair and Treagust (1999) recommend that teacher education programmes should support teachers so that they can effectively implement laboratory activities into their teaching in school, and should also encourage them to use a range of interactive methods including group discussion, group activities, and practical activities, which will help students to increase their level of understanding and, consequently, their level of achievement in physics. Cook and Taylor (1994) advise that the provision of laboratory assistants may lessen some problems regarding the availability and maintenance of laboratory equipment in secondary schools

## **2.6 The Potential Impact of ICT in Practical Physics Teaching**

If we look at the obstacles to progress in practical physics teaching, it seems possible that ICT can contribute to progress. This section will look at some research evidence which supports the use of information and communication technology (ICT) in enhancing learning through practical work.

Millar in Osborne and Dillion (2010) on 'Good Practice in Science Teaching' asserts that the use of interactive computer-based simulations in which students experiment with virtual manipulatives rather than physical manipulatives is one approach for enhancing the effectiveness of practical work. He points out some examples of studies in support of this assertion.

Johnstone and Wham (1982) highlight an issue in support of the use of information and communication technologies in practical work. They assert that practical activities have a high level of 'noise' which can distract students from their central purpose. In a typical practical activity, students have to deal simultaneously with the ideas and concepts that give the activity meaning, the practical manipulation of apparatus and materials, perhaps involving some quite fine motor skills, the planning and sequencing of actions to carry out procedures and record outcome, and the social interactions involved in group work. ICT offers a way of reducing this noise and helping students to focus on the central question the activity is addressing.

In research conducted by Zacharia and Anderson (2003), they investigated the use of simulations presented before laboratory activities designed to develop students' conceptual understanding of mechanics, waves and optics, and introductory thermal physics. The subjects in their study were 13 postgraduates (in-service and trainee teachers) students without physics qualifications who were randomly assigned to the simulation or non-simulation condition for different sub-topics within the overall teaching intervention. Diagnostic written tests were used to assess understanding. The

results indicated that exposure to simulations improved students' ability to offer acceptable predictions and explanations and led to significant conceptual changes in the area tested.

A similar study was conducted by Finkelstein et al. (2005) with a larger sample of undergraduate students ( $n = 231$ ) at a larger research university in the USA to investigate the effectiveness of an interactive computer simulation for teaching basic electric circuit theory. The experimental group ( $n = 99$ ) used the computer simulation, while the control group ( $n=132$ ) used real laboratory equipment. Assignment to these groups appears to have been on convenience grounds rather than random. The researchers reported that students who used the simulation achieved higher scores, both on an assessment of conceptual knowledge and on a task involving assembling a real circuit and explaining how it worked.

In a study with much younger learners, Klahr et al. (2007) varied several conditions, including the use of physical or virtual manipulatives, in a task involving the design and testing of toy cars. The participants were 56 school students (20 girls and 36 boys) with a mean age of 13.1 years from two middle schools in the USA. In this case, the researchers found no significant difference in learning outcomes between the conditions they tested but note that virtual manipulatives have pragmatic advantages in terms of class management and organization, and possibly cost, and might therefore be preferred for enabling active student involvement and engagement in learning.

In another study of learning of electric circuit theory, Zacharia (2007) used a sample of undergraduate students following a pre-service course for elementary school teachers in Cyprus. Students were assigned randomly to an experimental group ( $n = 45$ ) or a control group ( $n = 43$ ). The control group used real experimentation throughout, while the experimental group achieved higher gains on conceptual tests taken before, during and after the intervention. A similarly designed study of 68 students from the same pre-service teaching programme explored learning of heat and temperature (Zacharia and Constantinou, 2008). The experimental group used virtual manipulatives and the control group physical manipulatives. Unlike previous studies, the curriculum and the instructional approach were explicitly controlled. The groups made similar conceptual gains on written tests. In a subsequent investigation, involving 62 students of similar background (Zacharia et al., 2008), the experimental group used physical manipulatives followed by virtual manipulatives, and the control group physical manipulatives only. Here the experimental group made larger conceptual gains than the control group. In another similarly designed study of 66 10-11 year old students in Finland, Jaakola and Nurmi (2008) found that a combination of simulation and laboratory experimentation on electric circuits led to better learning outcomes than either approach used on its own.

In a recent study in Ghana, Antwi et al. (2014) investigated the effect of computer assisted instruction on Senior High School (SHS) students' interests and attitudes towards some selected concepts of electricity and magnetism. The study involved a whole class of Form 2 (Grade 11) Home Economics students in a Ghanaian Senior High School, selected through purposive sampling techniques and totalling 48 students (46 girls and 2 boys). The students were taken through a series Interactive Web quest Packages (IWebP) developed by the researchers with the help of software from SMART Technologies. Data was collected through the use of a Students' Observation Checklist (SOC) and a questionnaire on students' attitude towards the teaching and learning of electricity and magnetism. The findings from the SOC and the questionnaire indicated that students' interest was highly developed and that they showed positive attitude towards the teaching and learning of physics with computer assisted instruction.

Yang et al. (2007) also investigated and compared the impact of Internet Virtual Physics Laboratory (IVPL) instruction with traditional laboratory instruction on physics academic achievement, performance of science process skills, and computer attitudes of tenth grade students. One-hundred and fifty students from four classes at one private senior high school in Taoyuan County which is a special municipality in Taiwan, were sampled. All four classes contained 75 students who were equally divided into an experimental group and a control group. The pre-test results indicated that the students' entry-level physics academic achievement, science process skills, and computer attitudes were equal for both groups. On the post-test, the experimental group achieved significantly higher mean scores in physics academic achievement and science process skills. There was no significant difference in computer attitudes between the groups. They concluded that the Internet Virtual Physics Laboratory (IVPL) had potential to help tenth graders improve their physics academic achievement and science process skills.

This thesis is led by data on current practice in African schools. There is very little use being made of ICT in this context and therefore there will be little to report. However, the potential impact of ICT cannot be ignored. Many informed commentators have identified the likely benefits. According to Hubert (2006), the United Kingdom education system formally integrated information technology into the school curriculum when the national curriculum was devised and it was quickly realized that the work covered was useful in all subjects. Others have asserted that ICTs have the potential to accelerate, enrich, and deepen skills, to motivate and engage students, to help relate school experience to work practices, create economic viability for tomorrow's workers as well as strengthening teaching and helping schools to change (Davis and Tearle, 1999; Lemke and Coughlin, 1998 - cited by Yusuf, 2005)

This thesis will revisit the potential of ICTs in looking at the future strategies in the discussion chapter.

## **2.7 Summary**

This literature review was conducted with the purpose of investigating the present status and the potential role of practical work in the science/physics education curriculum. The literature focuses on the definition of practical work in science/physics teaching, aims of practical work, types of practical work and barriers to practical work. In addition, the potential role of ICT in practical physics was also reviewed.

Several authors cited in the literature review (Lemarechel and Tiberghien, 1999; Abraham and Millar, 2008; Hodson, 1998) agree that practical work is an activity that can be performed in a laboratory or outside in the field or in an ordinary classroom. Practical work is any science teaching and learning activity that involve the students, working individually or in small groups, manipulating or observing real objects and materials as opposed to the virtual world (SCORE, 2009). Practical work is seen as an integral part of the teaching learning process in science/physics education.

There are numerous studies on the aims of teaching practical work both within and outside the United Kingdom. Overall, there is a consensus that practical work helps in promoting manipulative skills, encouraging observation and description, verifying facts and principles already taught, creating motivation and interest for learning physics, developing creative thinking and problem-solving ability, developing critical attitude as well as developing conceptual understanding and intellectual ability (Hodson, 1990; Watson, 2000; Ghebremariam, 2000; Collins, 2001; Parkinson, 2004).

However, some authors highlighted the obstacles to progress in the teaching and learning of practical work. Existing constraints include; shortage of science/physics teachers in schools, lack of teaching time, limited laboratory facilities, teachers' insufficient knowledge, lack of laboratory assistants, overloaded curriculum, large class sizes, and lack of assessment of practical skills (Lazarowitz and Tamir, 1994; Cook and Taylor, 1994; Halai, 2008; Kansade, 2008).

Some strategies were proposed by researchers (Thair and Treagust, 1999) to overcome the existing limitations and promote the implementation of meaningful practical activities in physics. Thair and Treagust state that the benefit of practical work will remain uncertain if science /physics achievement tests neglect to measure skills developed during practical activities, modification of the physics curriculum in developing countries, and provision of laboratory assistants. In addition, they suggested that the teacher education programs should provide physics teachers with well-designed courses in practical work.

Finally, the literature review also covered papers which examined the potential impact of ICT on practical physics teaching. Several authors (Zacharia and Anderson, 2003; Klahr et al., 2007; Millar, 2010) have asserted that the use of ICT in practical physics is one approach for enhancing the effectiveness of practical work. They claimed that the use of ICT in practical physics has the potential to accelerate and improve students' achievement and skills.

The next chapter will look at the social and educational context of the countries involved in the study.

## **CHAPTER 3**

### **SUB-SAHARAN AFRICA — THE CONTEXT**

#### **3.1 Introduction**

This chapter provides relevant contextual information about the region of Sub-Saharan Africa and the five countries visited to gather data. The chapter includes general data on the characteristics of the population, economic status, etc. Also included are statistics on engagement with education and relevant expenditure with some international comparisons. In some cases, data is included on the evolution of indicators over time. The first section considers the region as a whole. Later sections provide additional insights into the individual countries visited. Unfortunately, the availability of data from the region is limited. Therefore, there is some inconsistency in the detail offered of individual countries. To some extent this can be mitigated by extrapolating from similar data but the tables and graphs still have some omissions. This should not affect the overall picture.

#### **3.2 Sub-Saharan Africa - General Data**

Sub-Saharan Africa is the part of the African continent that lies south of the Sahara. It contains all countries in Africa except the northern African countries of Algeria, Egypt, Libya, Morocco, Tunisia and Western Sahara. This section provides general background data on what is a profoundly inhomogeneous region in geographical, human, political, educational, religious and economic terms.

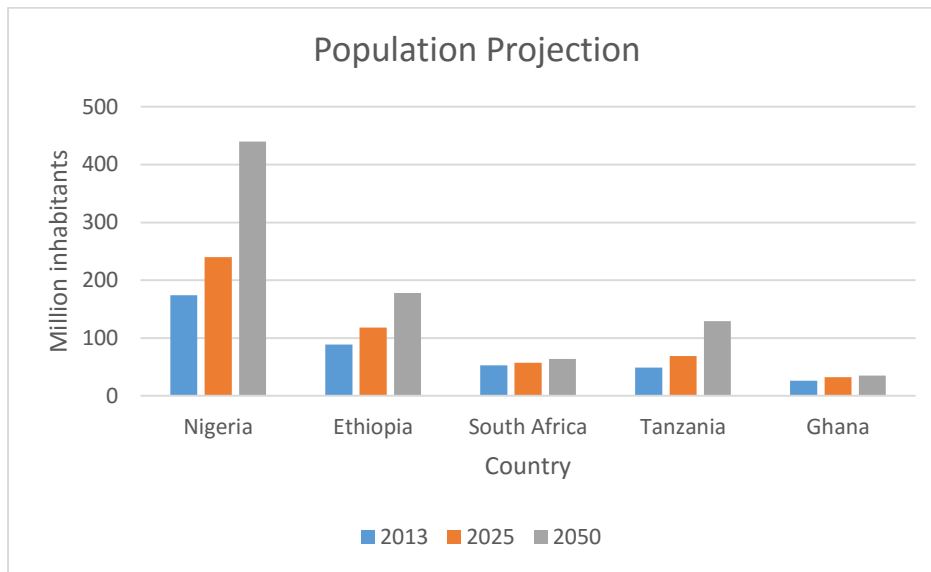
##### **3.2.1 Population**

According to the Population Reference Bureau (2013), Sub-Saharan Africa has a population of 926 million, i.e. the large majority of Africa's 1.1 billion inhabitants. The Sub-Saharan Africa population is expected to increase to 1.3 billion by 2025 with countries like Nigeria, Ethiopia, South Africa, Tanzania and Ghana responsible for a large percentage of the increase (Figure 3.1).

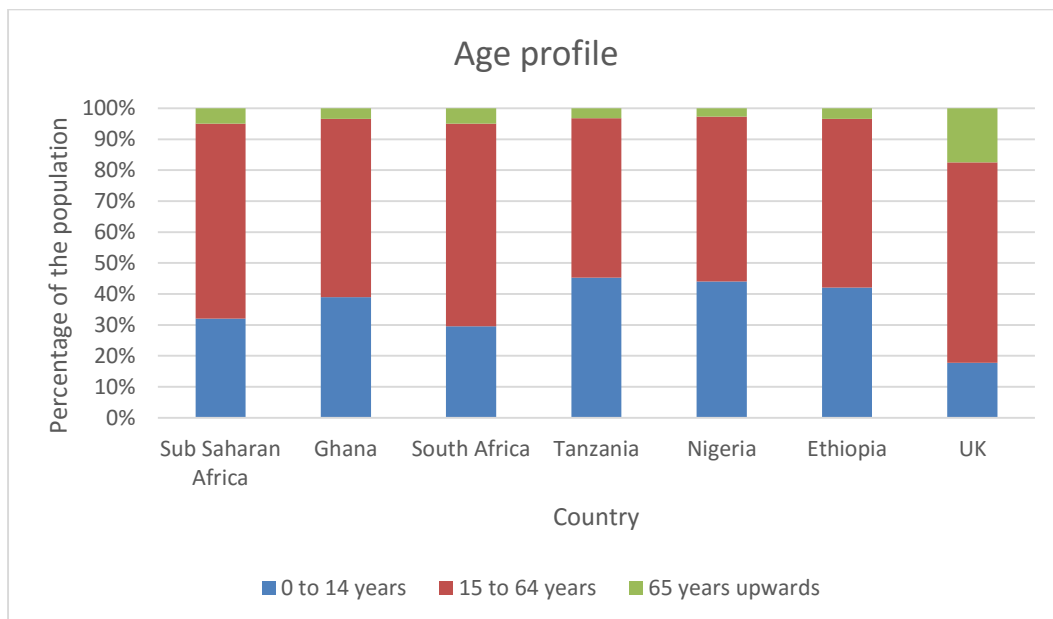
The high birth rate is reflected in the age profiles of the populations (Figure 3.2). Although the overall figure of 63% of the population within the age bracket of 15-64 years (the 'working population') is similar to that for the UK, the proportion below 14 years of age is very large. For example 44% of Nigerians are in this 'dependent' age bracket.

The rate of population increase in the region is greater than in any other sub-continental region. It poses great problems but could, if managed successfully, provide a significant opportunity as the most economically productive young-adult population swells. However, the geometric increase in

population has led to the high unemployment rates which are quite evident in Nigeria, South Africa and Ghana.



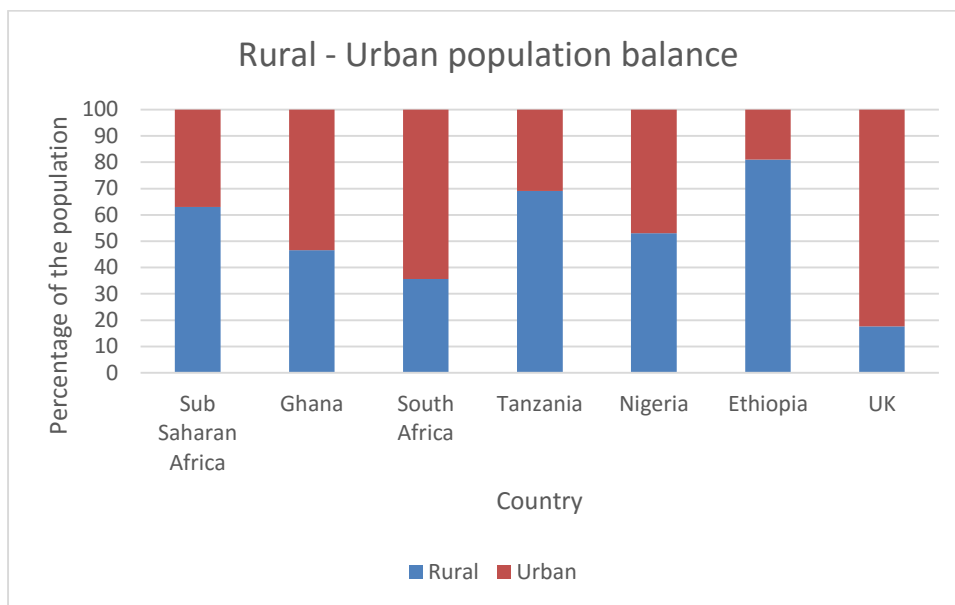
**Figure 3.1:** Projected population increases for the countries visited in this study. (Population Reference Bureau, 2013)



**Figure 3.2:** The age profiles of the populations of selected countries in Sub-Saharan Africa (Population Census Bureau, 2013)

### 3.2.2 Rural-Urban Population Balance

About 63% of the Sub-Saharan Africa population lives in areas that are lacking in social amenities. Within that overall regional figure, there is diversity that reflects the level of economic development (Figure 3.3). More than 70% of the Ethiopian and Tanzanian populations are based in rural settings. At the other extreme the proportion living in rural settings in South Africa and Ghana are both less than 50%. However, even these lower values are very different from a developed economy such as the UK where more than 80% of the population live in urban areas.



**Figure 3.3:** The percentages of the populations living in rural and urban settings in selected countries. (Population Reference Bureau, 2013)

### 3.2.3 Economic Development

In 2014, a report from the World Bank indicated that the economic growth rate in Sub-Saharan Africa had risen to 4.7% in 2013, with a rate of 5.2% forecast for 2014 (World Bank, 2014). In the same report it was noted that the continued rise in the economy was due to increasing investment in infrastructure and resources (World Bank, 2014). According to the Population Reference Bureau (2013), the Gross Domestic Product (GDP) growth in Sub-Saharan Africa was 6.3% over the four year period (2007-2011). Within this overall figure the countries studied in this thesis all had broadly similar growth rates during a period when the UK, along with other more developed economies experienced negative growth (Table 3.1).

In spite of the growth in GDP, the gross national income at purchasing power parity (GNI-PPP) per capita in 2012 for Sub-Saharan Africa remained very low compared with developed economy

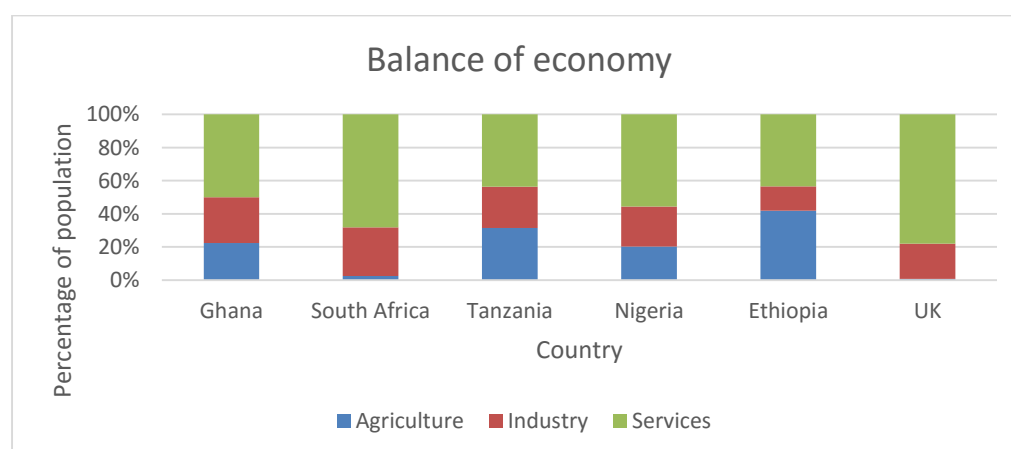


countries such as the UK (Table 3.1). Within the region, GNI-PPP varied substantially with the figures for Tanzania and Ethiopia, one order of magnitude less than the value for South Africa.

**Table 3.1:** Gross domestic product growth in (%) (Population Reference Bureau, 2013).

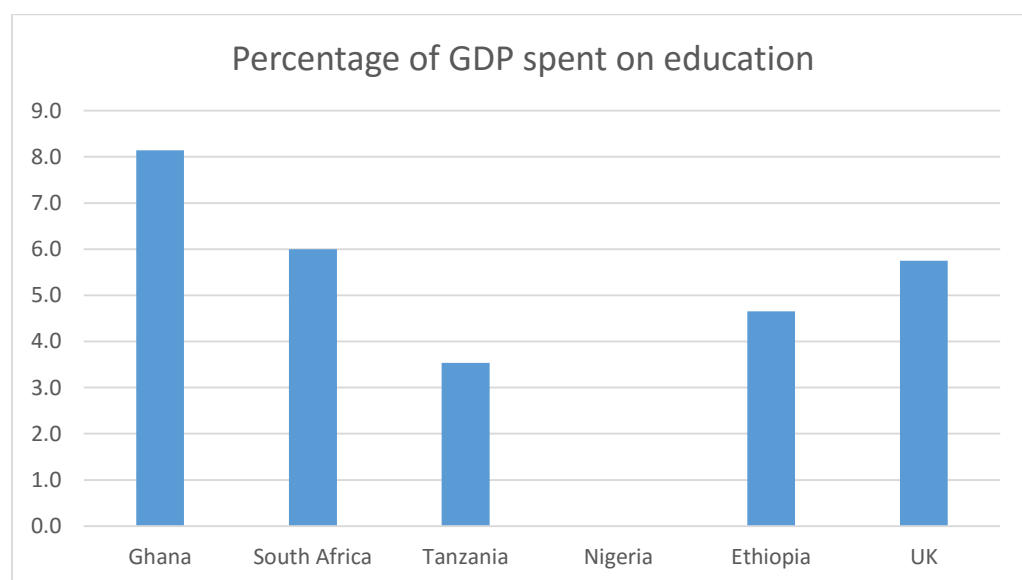
Countries	GDP Growth (%) (2007-2011)	GNI-PPP Per Capita (\$US) 2012
<b>Sub-Saharan Africa (overall)</b>	6.3	2,240
<b>Ghana</b>	7.7	1940
<b>Nigeria</b>	6.4	2420
<b>Tanzania</b>	5.8	1590
<b>South Africa</b>	5.9	11,190
<b>Ethiopia</b>	7.6	1140
<b>UK</b>	-2.4	35,800

Many commentators have pointed to the link between economic growth and extractive industries in Sub-Saharan Africa (Morris et al, 2014). Africa contributes heavily to production and known reserves of many minerals, for example cobalt, platinum, diamonds, bauxite etc., and increasingly petrochemicals (British Geological Survey, 2014). The very impressive growth figures quoted above were heavily reliant on a boom in commodities prices and inward investment aimed at increasing extractive industry capacity. This can lead to economic instability and the recent economic downturn has affected many African economies heavily. However, the catalyst provided by an expansion of extractive industry can stimulate longer term and broader growth. It can stimulate the need for local engineers and other professionals.



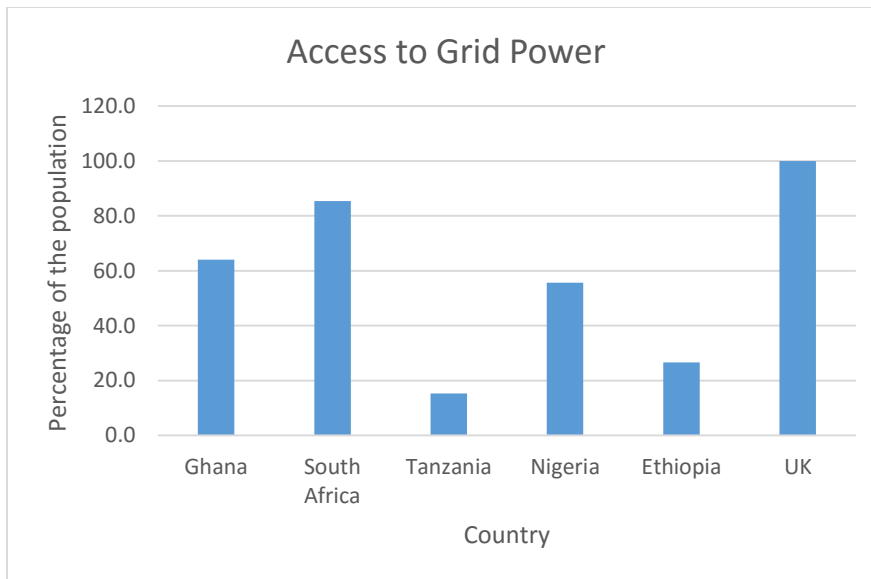
**Figure 3.4:** The sectoral contributions to the GDPs of selected countries, with the UK as a basis of comparison (World Bank, 2014).

In spite of the expansion of extractive industries, many Sub-Saharan economies are still heavily reliant on agriculture and on service occupations (Figure 3.4). The latter tend to be in low added-value roles rather than the banking and ICT services which underpin many developed economy countries. It should not be assumed that all countries will move to the UK model of a very small economic contribution from agriculture. Several African countries are now exploiting their agricultural capacity, e.g. Kenyan and Ethiopian horticultural industries are major suppliers for European cut flower and vegetable markets. This has been proposed as an alternative driver of development (Brooks et al., 2013).

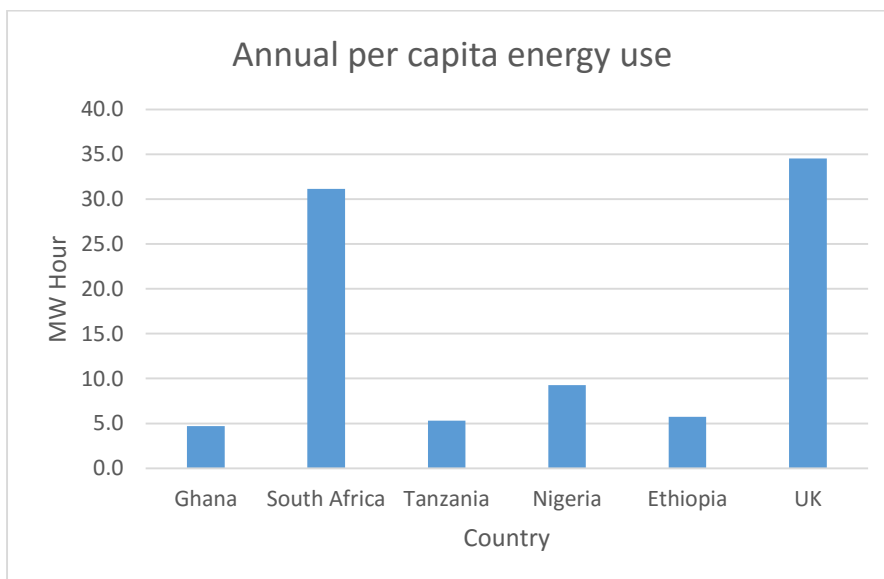


**Figure 3.5:** The percentage of GDP spent on education (all levels) in selected countries (Source: World Bank, 2013. The data is not available for Nigeria.)

In spite of the many budget pressures, the region has invested significantly in education, as shown in Figure 3.5. Much of this investment has gone into expanding access to primary education, one of the Millennium Goals. The proportion of GDP spent on education is of the same order as in economically developed countries such as the UK.

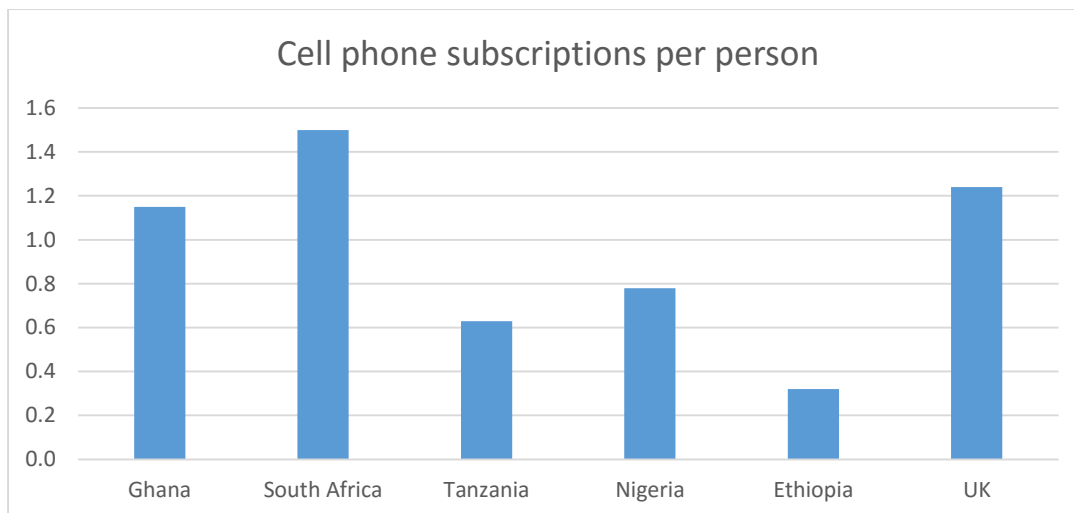


**Figure 3.6:** The percentage of population with home access to grid power (Source: World Bank, 2013).



**Figure 3.7:** The annual per capita use of energy (Source: World Bank, 2013).

Access to grid energy and the amount of energy used are indicators of economic development and are relevant to educational opportunity. It is not possible to deploy technology fully in education without reliable grid power. Even basic homework is compromised by lack of light. Similarly, students without access to energy-heavy transport systems may not be able to attend remote secondary schools. Figures 3.6 and 3.7 provide relevant data. It is quite clear that many educational reforms cannot be achieved without increasing access to energy.



**Figure 3.8:** Cell phone subscriptions per person in selected countries (Source: World Bank, 2014).

In some countries, multiple subscriptions provide flexibility to deal with patchy network coverage. However, the communication systems are well developed in many Sub-Saharan African countries. The use of cellular phones is widespread (Figure 3.8) and has proved a stimulus to small scale business. The cell phone may be influential in reducing corruption as it allows easy bank payment and tracing of transactions.

### 3.2.4 Enrolment in Education

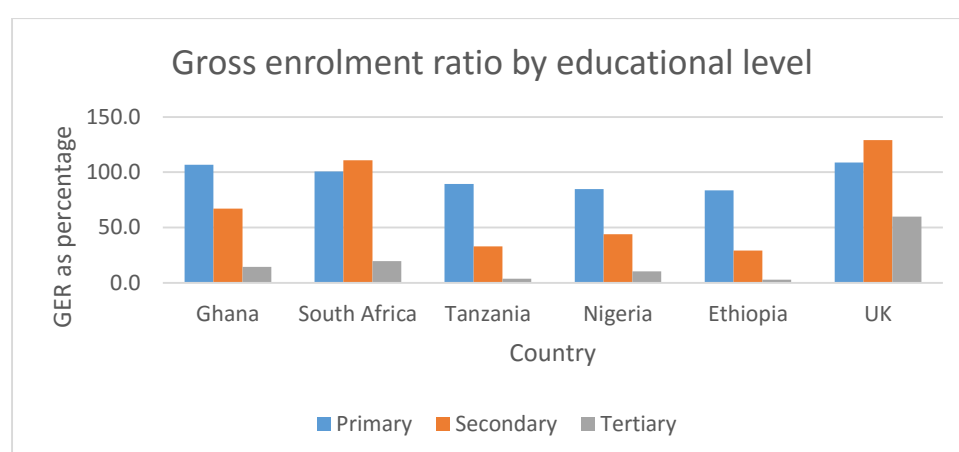
Several measures are used to quantify educational enrolment. The most often quoted is the gross enrolment ratio (GER) which is defined as the ratio of total enrolment at a particular level, regardless of age, to the population of the age group that officially corresponds to the same level of education. The GER may be greater than 100% because of the presence of older students, e.g. mature students at tertiary level.

Enrolments at primary, secondary and tertiary levels in Sub-Saharan Africa have increased dramatically in recent years. Figure 3.9 shows that universal primary education is becoming closer to a reality for the visited countries in Sub-Saharan Africa.

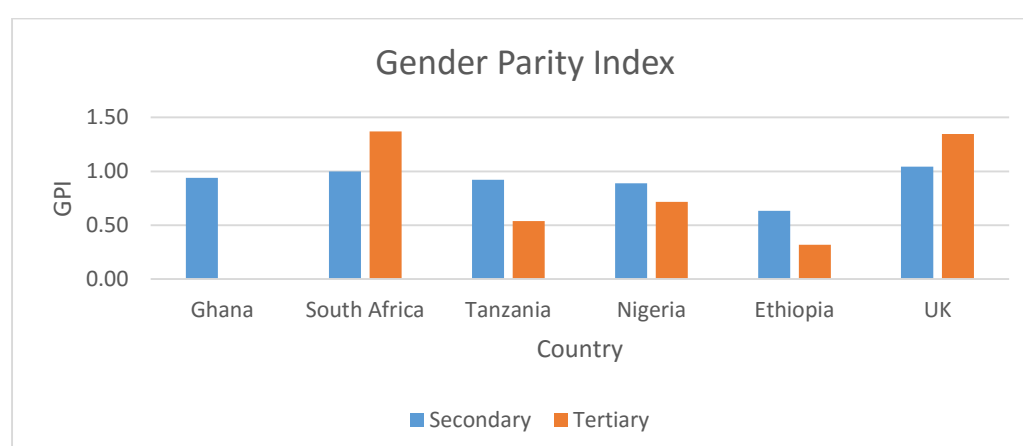
Despite the increase in enrolment, there were reports from UNESCO in 2011 that more than 20 million children of lower secondary school age in Sub-Saharan Africa were not gaining the benefit of a secondary education as a result of unaffordable costs and lack of teaching space (UNESCO Institute of Statistics, 2011). At secondary level, the GER data hide a major problem of completion. In many countries, a minority of students complete lower secondary education and there are profound differences in gender enrolment and completion (World Bank Development Indicators, 2015). The

data for the Gender Parity Index GPI, defined as the ratio of the GER values for females to males, indicate that progress is uneven and that females remain disadvantaged (Figure 3.8).

According to Mohamedbhai (2011), access to tertiary education has been limited to a small and privileged minority. This remains true. According to the World Bank (2014), the tertiary gross enrolment rate in Sub-Saharan Africa is still very low, typically between 5% and 15%. These figures are inflated by the prevalence of part time courses which count towards enrolment but do not contribute fully to completion. The enrolment for countries visited in this study range from South Africa (19.7%) to Ethiopia (2.8%), in comparison to the UK which has a gross enrolment ratio of 59.8% at tertiary level. There are major gender differences in tertiary engagement throughout Sub-Saharan Africa.



**Figure 3.9:** The 2013 gross enrolment ratios (expressed as percentages) for each educational level in selected countries (Source: World Bank, 2014).



**Figure 3.10:** Gender Parity Index for secondary and tertiary levels in selected countries. No data has been found for Ghana at tertiary level.

### **3.3 Commentaries on Individual Countries**

In this section there are brief discussions of background issues relevant to the study for each of the countries where research data was acquired, i.e. Nigeria, Ghana, South Africa and Tanzania.

Although a visit was also made to Ethiopia, no formal data gathering was possible in that country.

#### **3.3.1 Ghana Commentary**

A 2013 report from the World Bank shows that Ghana has a population of 25.9 million with a female/male balance of 50.5% to 49.5% (World Bank, 2013). The population inhabits ten regions with varying ethnic, linguistic and religious groups. About 70% of the population live in the southern half of the country (CIA World Fact Book, 2016). A wide variety of languages are spoken with about 30% having English as their first language. Approximately 70% of the Ghanaian population are Christian and 17% are Muslim. About 53% live in urban settings while the remaining 47% are rural dwellers as shown in Figure 3.2. The present rate of urbanization is about 3.4% per year, a high value that reflects rapid population growth and the need to find employment.

#### **Economy**

The drivers of the economy for Ghana are the service sectors which constitute 49.9% of the economy followed by industry and agriculture at 27.7% and 22.4% respectively (Figure 3.3). According to a report by the Africa Development Bank published in Africa Economic Outlook (AEO,2015), the economy of Ghana is likely to be bolstered by an increase in oil and gas production, private sector investment, improved public infrastructures and the country's political stability. Gold and cocoa production and individual remittances are major source of foreign exchange (African Economic Outlook, 2015). The emerging oil and gas extraction industries have been affected by recent reductions in the price of associated products.

#### **Education System**

The Ghanaian education system comprises three phases: basic education, secondary education and tertiary education. The Ministry of Education has overall responsibility for education, but the National Council for Higher Education is responsible for the administration of tertiary education.

The country has a Strategic Plan for Education covering the period 2010 to 2020 (Ghana MoE, 2010). Although the plan has a focus on basic education, one of its 10 Policy Goals is to 'Expand Science and Technology Education'. This goal is reflected in 'a sub-sector-strategy' for Science, Technology and Mathematics education that includes the following:

- Strengthen science education in all aspects of the educational system at the Basic and Senior Secondary levels
- Introduce Science and Technical and Vocational Education and Training (TVET) innovations within the system
- Ensure that, by 2020, 60% of all students in the universities and 80% in the polytechnics and vocational institutions are registered in science and technology-related disciplines
- Provide special incentives for students and graduates of Science and Technology.

In addition the ICT in Education strategy includes;

- Modernise the educational system through ICTs to improve the quality of education and training at all levels thereby expanding access to education, training (in particular teacher professional development) and research resources and facilities.
- Use ICTs to orientate all levels of the country's educational system to the teaching and learning of all subjects, including science and technology.

There has been limited progress towards achieving these goals. The majority of the country's graduates are in humanities subjects and there is a significant graduate unemployment problem.

**Table 3.2:** Data on enrolment and the number of institutions providing educational opportunity in Ghana (Ghana MoE, 2013). The targets were published as part of the 2010-20 MoE Education Strategic Plan (Ghana MoE, 2010).

	<b>Pre-school</b>	<b>Primary</b>	<b>Junior Secondary</b>	<b>Senior Secondary</b>	<b>Tertiary incl. Vocational</b>
<b>Enrolment</b>	1,604,505	4,105,913	1,452,585	842,587	61,496
<b>Gross Enrolment Ratio (GER) in % (target for 2015)</b>	113.8 (100)	105.0 (107)	82.2 (90)	36.8 (36)	2.7 (not set)
<b>Public institutions</b>	13,305	14,112	8,818	535	107
<b>Private institutions</b>	5,972	5,742	3,618	293	74
<b>Total institutions</b>	19,277	19,854	12,436	828	181

## **Mandatory Basic Education**

Primary and junior secondary levels are included in “basic education” which is free and compulsory. Students begin their 6-years primary education at age six and pass into a junior secondary school system for 3 years of academic, technical and vocational education. The primary curriculum includes General Science. The lower secondary or junior high school ends with the Basic Education Certificate Examination (BECE). The curriculum includes Integrated Science. Ghana has invested heavily in education and has achieved significant increases in primary and secondary engagement (Table 3.2). A UNICEF report in 2012 indicated the primary pupil-teacher ratio was 31 and the adult literacy and youth literacy rates stood at 67% and 81% respectively at that time. The gender parity index for Ghana is approaching 1 at secondary level (Figure 3.9). The private sector makes a major contribution to basic education and to higher level education (Table 3.2).

## **Senior Secondary Education**

Senior High School lasts for 3 years. The curriculum is composed of 4 core subjects, and either 3 or 4 elective subjects. The core subjects are English language, mathematics, integrated science (science, ICT and environmental studies) and social studies (economics, geography, history and government). The students then choose elective subjects from 5 available programmes: agriculture, general (divided into two options: arts or science), business, vocational, and technical. University admission is based on student performance in the West Africa Senior School Certificate Examination WASSCE which is an examination used by the Anglophone West African countries (Ghana, Nigeria, Gambia, Sierra Leone and Liberia) to facilitate university entrance across their borders.

The Curriculum Research and Development Division (CRDD) (a division of the Ministry of Education responsible for curriculum design) highlighted the aims of the Senior High School Physics programme for Ghana as:

- to provide, through well designed studies of experiment and practical physics, a worthwhile hands-on educational experience to become well informed and productive citizens;
- to enable the Ghanaian society to function effectively in a scientific and technological era, where many utilities require basic physics knowledge, skills and appropriate attitudes for operations;
- to recognise the usefulness, utilization and limitations of the scientific method in all spheres of life;



- to raise the awareness of inter-relationships between physics and industry, Information, and Communication Technology (ICT), Agriculture, Health and other daily experiences;
- to develop in students, skills and attitudes that will enable them to practise science in the most efficient and cost effective way;
- to develop in students desirable attitudes and values such as precision, honesty, objectivity, accuracy, perseverance, flexibility, curiosity and creativity;
- To stimulate and sustain students' interest in physics as a useful tool for the transformation of society. (MoE, 2008)

### **Tertiary Education**

The National Council for Tertiary Education (NCTE) is responsible for tertiary education. Atuahene and Ansah (2013) stated that tertiary education in Ghana has witnessed tremendous growth in the last twenty years in terms of both enrolment and infrastructures. They stated that there were 55 universities (6 public and 49 private institutions) which offered an academic education from Bachelor degree to PhD. There has been rapid expansion in the sector and, in April 2016, the National Accreditation Board for Ghana lists 10 Public universities and 69 degree awarding institutions (National Accreditation Board, 2016). Almost all of the latter offer degrees that are accredited by public or overseas universities and the majority have religious affiliations.

There are also 10 polytechnics that offer vocational education and many colleges of education (37 public and 8 private). These colleges offer a three-year curriculum that leads to the Diploma in Basic Education (DBE). The holders of the DBE are allowed to teach at every level of basic education. There are also two universities (Cape Coast and Winneba) who train teachers for a four year Bachelor degree which qualifies graduates to teach in any pre-tertiary education institutions (Kwane and Setti, 2014).

The tertiary education system had 262000 students in 2011/2012 with 202,000 in the public sector and 60,000 in the private sector (MoE, 2013).

### **Funding**

Ghana's expenditure on education has increased tremendously in the last six years. A source from the Ministry of Education revealed that the budget allocation increased from GH¢ 1.7 billion in 2010 to GH¢ 5.8 billion in 2014. This trend has continued. In 2015, GH¢ 6.7 billion, representing 21 percent of the national budget, was allocated to the education sector (Ghana MoE, 2015). About 8.1% of the gross domestic product (Figure 3.4) was devoted to education at all levels.

### **3.3.2 South Africa Commentary**

In mid-2013, the South African population was estimated to be 53 million and is expected to increase to 56.9 million by 2025 (Population Reference Bureau, 2013). About 64 percent of the South African population lives in urban areas with 36 percent living in rural settlements (Figure 3.2). South Africa has five listed racial groups which includes 79.2% Black African, 8.9% White, 8.8% Colored, 2.5% Indian/Asian and 0.5% other (NBS, 2011). The country has 11 official languages which include: Afrikaans, English, Ndebele, Xhosa, Zulu, Sepedi, Sesotho, Tswana, Swati, Venda and Tsonga.

#### **Economy**

The World Bank indicates that South Africa is the second largest economy in Sub-Saharan Africa behind Nigeria and is one of the world's largest producers and exporters of gold and platinum (World Bank, 2012). The country also exports other metals, minerals, machinery and equipment. The majority contribution to the economy is services (Figure 3.3).

More than 80% of the South African population has access to grid power. This has helped the development of industries in South Africa compared to Nigeria where most of the industries are powered by generator. South Africa is also prominent in the use of cell phones as it has the highest subscription rate in Sub-Saharan Africa.

#### **Education system**

The education system in South Africa is governed by the Department of Basic Education (DBE), which is responsible for primary and secondary schools, and the Department of Higher Education and Training (DHET), which is responsible for tertiary education and vocational training. The nine provinces in South Africa also have their own education departments that are responsible for implementing the policies of the national department, as well as dealing with local issues (Department of Basic Education, 2015). In the South Africa National Qualification Framework NQF there are 3 bands of education: General Education and Training GET which includes Grade 0 plus Grades 1 to 9, Further Education and Training FET which includes both Grades 10-12 and non-higher education vocational training, and Higher Education and Training HET (DBE, 2015).

The Department of Basic Education is operating with a strategy set out in 'Action Plan to 2014 - Towards the Realization of Schooling 2025' (Department of Basic Education, 2014). This includes 27 goals, only one of which refers explicitly to science, i.e. increase the number of Grade 12 learners who pass physical science. However, the fuller text includes several other relevant aspirations; improved gender parity in exam results, provision of science textbooks, a science laboratory for each

primary school, and enhanced access to e-resources. In addition the Plan advocates improvement in *‘the professionalism, teaching skills, subject knowledge and computer literacy of teachers throughout their entire careers’*.

Given its large number of official languages, South Africa has a language of instruction policy that the *‘right to choose the language of learning and teaching is vested in the individual. This right has, however, to be exercised within the overall framework of the obligation on the education system to promote multilingualism’* (Languages in Education Policy, 1997). It is difficult to generalize about present practice as it varies but it is common for the ‘local’ language to predominate in the first grades and for English to be more prevalent at higher school grades. At tertiary level English dominates usage with Afrikaans as the main alternative.

The Department of Education and Training included an explicit reference to science as a priority area as one of five desired outcomes in the Strategic Plan for 2010-11 to 2014/15, i.e. increase access to high level occupationally-directed programmes in needed areas such as engineering, health sciences, natural and physical sciences, as well as increasing the graduate output of teachers (Department for Higher Education and Training, 2010). The new Strategic Plan consolidates its predecessor and sets numerical targets for graduates.

**Table 3.3:** Enrolment and gender parity data for primary, secondary and tertiary education in South Africa (Department of Basic Education, 2015: Department for Higher Education and Training, 2015).

	Pre school	Basic Education			FET College	HEIs
		Foundation G1 to G3	Intermediate G4 to G6	Senior G7 to G9	G9 to G12	
<b>Gross Enrolment Ratio</b>		99%		89%		
<b>Gender Parity Index</b>		0.96		1.14	1.38	1.37
<b>Public enrolment</b>	25k	3,976k	2,694k	2,813k	640k	984k
<b>Number of public institutions</b>	24,136				50	23
<b>Private enrolment</b>	19k	168k	104k	104k	155k	120k
<b>Number of private institutions</b>	1,584				627	113
<b>Total enrolment</b>	44k	4,144k	2,797k	2,918k	795k	1,104k

Enrolments at all educational levels in South Africa are dominated by public institutions. However, there is a difference in outcomes with the least privileged not achieving the exam results sought in national planning and the most privileged (often attending private schools) achieving high standards (Department of Basic Education, 2015). The gender parity index for South Africa indicates that females are achieving better outcomes than the males, a situation that reflects the present position in many economically developed countries.

### **Mandatory Basic Education**

The foundation (Grade 1 to 3), intermediate (Grades 4 to 6) and the senior (Grades 7 to 9) phases of basic education are officially called General Education and Training (GET) and are compulsory for children aged 7 to 15. Further Education and Training (FET) includes Grades 10-12 as well as non-higher education vocational training facilities.

The 2013 Statistical report from the Department of Basic Education shows the student-teacher ratio to be in region of 30 to 1. The report also indicated that the ratio of students per teacher in all the provinces is nearly the same.

Data emanating from the Curriculum and Assessment Policy Statement (CAPS, 2011) indicated the purposes of teaching practical physics as follows.

- To make learners aware of their environment and to equip learners with investigative skills relating to physical phenomena e.g. classifying, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem solving and reflective skills.
- To promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; and understanding of the nature of science and its relationships to technology, society and the environment.
- To prepare learners for future learning, specialist learning, employment, citizenship, holistic development, socioeconomic development and environmental management. It plays an increasing role in the lives of all South Africans owing to their influence on scientific and technological development which are necessary for the country's economic growth and the social wellbeing of its people (CAPS, 2011)

## **Tertiary Education**

Tertiary education in South Africa is supervised by the Ministry of Higher Education and Training. There are 23 state-funded tertiary institutions: 11 universities, 6 universities of technology and 6 comprehensive institutions. The private sector has a large number of small institutions and very limited enrolment (Table 3.3). University entrance requires success in matriculation exams, with a minimum of three subjects passed at the higher rather than standard level. Some universities set additional academic requirements. Despite being supervised by the Department of Higher Education and Training, most universities have substantial autonomy.

Due to its vibrant higher education system, several of South Africa's universities are world-class academic institutions at the cutting edge of research in specific spheres. This high standing has attracted many foreign students, especially from West Africa.

## **Funding**

South Africa spends a very large share of its government budget on education. In 2013, South Africa spent 21% of the national budget on education with 10% of that education budget allocated for higher education. An online report about Education in South Africa (EIS) stated that government spending on basic education during 2015/2016 is estimated at R203 billion (R represents Rand which is the unit of South African currency). Over the next three years, roughly R640 billion will go towards basic education (EIS, 2015).

### **3.3.3 Nigeria Commentary**

Nigeria is the most populous country in Africa with a population of 170 million in 2013 which is expected to increase to 440 million by 2050 (Population Reference Bureau, 2013). Nigeria is dominated by three major tribes which are the Yoruba having their base in the southwest, the Ibo in the eastern part of the country and Hausa in the northern region. The various tribes have their own local languages but English is the official language and is used as the official medium of instruction in schools and universities.

## **Economy**

As shown above, the Nigerian economy is based on substantial engagement in (subsistence) agriculture and low value services. However, in the last two decades, Government revenue has been increasingly dominated by oil revenues. In 2015, the proportion was 70% though this is being threatened by the collapse in oil prices. The oil industry has spawned substantial industrial investment but this is largely confined to the south of the country.

In spite of its oil wealth, almost half of Nigerians do not have access to a power grid supply (Figure 3.5). Even for those who do have access, interruptions in supply are common and the use of standby generators is widespread.

## **Education System**

Nigeria operates under a system of Universal Basic Education (UBE). Students attend six years of primary school and three years of junior secondary, thus there are nine years of compulsory and uninterrupted schooling. This is followed by three optional years of senior secondary schooling and four to six years of tertiary education depending on the course of study. The federal Ministry of Education plays the dominant role in regulating the school education sector, engaging in policy formation and ensuring quality control. However, operational matters are largely the responsibility of State (secondary) schools and Local (primary) schools. The Federal Government is more directly involved with tertiary education than it is with school education, largely through the National Universities Commission.

Stressing the importance of science education, the National Policy on Education 2004 stated that the goals of science education were to:

- (I) Cultivate inquiring, knowing and rational minds for the conduct of a good life and democracy;
- (II) Produce scientists for national development;
- (III) Service studies in technology and the cause of technological development; and
- (IV) Provide knowledge and understanding of the complexity of the physical world, the forms and the conduct of life. (NPE, 2004).

The National Policy on Education further stated that *'Government shall popularize the study of the sciences and the production of an adequate number of scientists to inspire and support national development'* (NPE, 2004). The National Policy on Education for 2013 is not as specific on science but emphasizes the need for the curriculum to serve the practical needs of the nation.

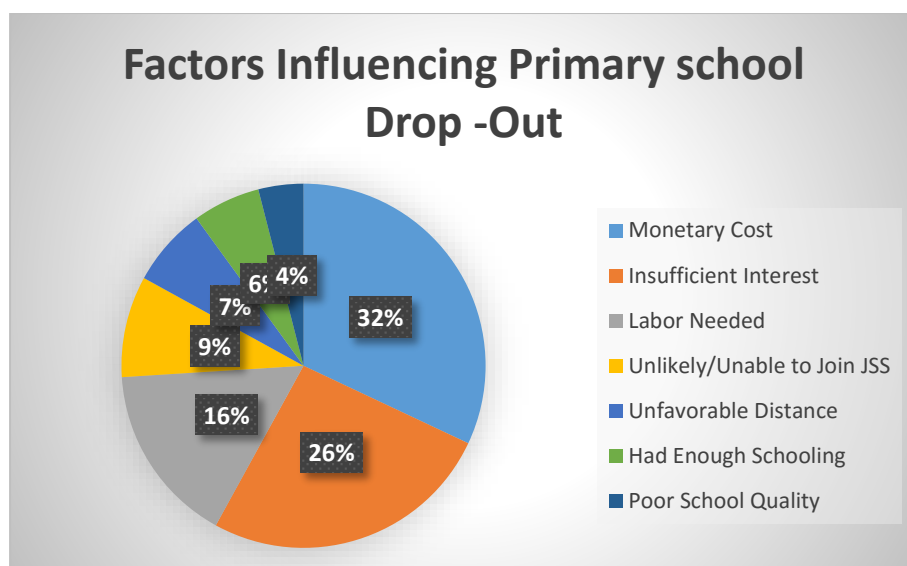
**Table 3.4:** Enrolment and gender parity data for primary, secondary and tertiary education in Nigeria (Basic Education Data, 2012: UIS, 2012)

	<b>Pre-school</b>	<b>Primary</b>	<b>Junior Secondary</b>	<b>Senior Secondary</b>	<b>Tertiary Institution</b>
<b>Gross Enrolment Ratio (GER)</b>	13.4%	84.7%	46.3%	41.1%	10.0%
<b>Enrolment</b>	2,2978k	23,477k	4,470k	4,047k	1,700k
<b>No. of Teachers</b>	78,540	550,238	176,729		
<b>Total Institutions</b>	28,565	59,382	11,561		140

The Nigerian National Bureau of Statistics Report on Literacy in 2010 indicated that Nigeria's adult literacy rate in the English language was 58% (male 65%, female 50%) and the youth rate was 76% (male 81%, female 71%) (National Bureau of Statistics, 2010). There are a large number of out-of-school children and young adults with limited literacy and numeracy skills who have little hope of ever joining the formal workforce. In 2010, 20% of the rural population had never attended any school. Education indicators are poor nationwide, and the greatest need for assistance is in the predominantly Muslim North which has been ravaged by the activities of the Boko Haram insurgency since 2003.

### **Mandatory Basic Education**

The first nine years of basic education is mandatory but less than one-third of children proceed to Senior Secondary School (SSS). Non-school attendance is highest among states in the Northeast and Northwest zones. 72% of primary age children do not attend school in Borno state. This compares with less than 3% in most southern zones. The primary school curriculum is geared toward providing permanent literacy, laying a sound basis for scientific, critical and reflective thinking, and equipping children with the core life skills to function effectively in society. Figure 3.10 shows the various reasons given for drop-out from primary schools (Nigeria Education Fact Sheet, 2012). It is clear that, for many families, education is limited by cost, access and doubts about the relevance and quality of what is offered. These data also reflect the lack of employment opportunities, particularly in the North of the country.



**Figure 3.11:** The factors influencing drop-out from primary schools in Nigeria (Source: Nigeria Education Fact Sheet, 2012).

### Senior Secondary Education

Students spend three years in senior secondary school (SSS) after which they are required to take the Senior School Leaving Certificate SSCE which qualifies students to proceed to tertiary institutions. The common core curriculum at the senior secondary level consists of: English, one Nigerian Language, mathematics, one science subject, one social science subject, and agricultural science or a vocational subject. In addition students must take three elective subjects, one of which may be dropped in the third year. However, science students take English, Mathematics, Physics and Biology as compulsory subjects. It must be noted that most students at the senior secondary level tend to choose subjects in humanities and social sciences rather than in sciences because of the perceived difficulty of the science subjects especially Physics. In 2010, 80% of students failed the SSCE because they did not have credit passes in all of English, Mathematics and three other subjects. Students who achieve five credits including English and Mathematic can enroll for the Unified Tertiary Matriculation Examination which is the major means of gaining admission into Nigeria Universities.

The Nigerian Educational Research and Development Council (a body responsible for designing the curriculum for secondary schools in Nigeria) stated the general objectives of the practical physics curriculum:

- To provide basic literacy in physics for functional living in the society;
- To acquire basics concepts and principles of physics as a preparation for further studies;



- To acquire essential scientific skills and attitude as a preparation for technological application of physics; and
- To stimulate and enhance creativity (NERDC,2009)

### **Tertiary education**

At the time of writing there are 140 universities in Nigeria. In 2015, these had the capacity to admit approximately 500,000 of the 1,700,000 students who were successful in the Unified Tertiary Matriculation Examination.

The National Universities Commission (NUC) is the government umbrella organization that oversees the administration of higher education in Nigeria. It approves and accredits all university programs. The NUC website lists 41 federal universities, 40 state universities and 59 private universities (National Universities Commission, 2016). Over the last few years it has overseen large-scale expansion in the number of universities while attempting to maintain and enhance quality.

In addition to universities, there are 59 federal state polytechnic colleges, several privately owned polytechnics, monotechnics and colleges of education across the country. They were established to train technical, mid-level manpower and teachers. There are plans to upgrade some of these colleges to allow them to award degrees.

For some time, the Nigerian government has sought to place greater emphasis on science and technology education at tertiary level but this has had limited impact. The policy was restated following the national elections in 2015 with plans for six new universities of science and technology (ICEF, 2015). However, there are academic staff shortages in all areas, particularly in the critical areas of science and technology.

### **Funding for Education**

There is an absence of internationally validated data on the funding of education in Nigeria. In 2016, Nigeria budgeted about 370 billion Naira of its 6 trillion Naira budget on education. This represents about 6.2% of the total budget. However, the relationship of the national budget to the GDP is not known. For many countries in Sub-Saharan Africa, it is less than 10% which may imply that the proportion of GDP allocated to education is low in Nigeria. It is certain, however, that the allocation is not able to meet all needs, given the exceptional birth rate.

A 2014 study by UNESCO asserted that the world needed four million additional teachers by 2015 and 12 million by 2020 (UIS, 2014). This lack of qualified teachers is particularly acute in Sub-Saharan Africa and Nigeria is one of the worst hit countries. The study indicates that the country needs to

spend an additional \$1.8bn to shore up the teaching force particularly in the field of science. The paper further suggested that *'boosting science will hardly happen through an undue privilege of science over the arts or humanities because the pedagogical approach is rigid and oriented towards cultivation of existing knowledge rather than critically advancing it. As a result, Nigeria currently lags far behind on indices that measure national educational progress, ranking behind countries like Ghana and South Africa'*. The report suggests that Nigeria should promote independent thinking and stimulate creativity.

### **3.3.4 Tanzania Commentary**

Tanzania is an East African country with a population of 45 million. Its political capital is Dodoma, while its main commercial city is Dar es Salaam. Both Swahili and English are official languages but the majority of dialogue within local communities take place in the mother tongue, of which there are about 140. The country is diverse in geography, climate, ethnicity and religion but is centralized in its politics and governance structures. The population is about one third Christian and one third Muslim with the remainder practicing traditional African beliefs

#### **Economy**

Tanzania is one of the least developed countries in Africa. The GDP per capita is below average for Sub-Saharan African countries – \$1813 per year (World Bank, 2014). In the last few years, the economy has grown quickly through expansion of extractive industries, particularly gold mining which accounts for the vast majority (nearly 90%) of its exports. However, agriculture is also developing rapidly.

The recent growth has not been felt across all regions and parts of the population and the country's Global Health Index is ranked last but one in the East African Community. Malaria is a major problem. In 2008 there were 11.5 million cases reported, approximately one quarter of the population (Rollback malaria partnership, 2012).

Tanzania has had limited external economic links and has not been as deeply affected as many other countries by the world recession of the last 8 years. The use of cell phones increases at a fast pace in Sub-Saharan Africa with about 70% annual increase (as shown in Figure 3.8) and Tanzania is not left out.

#### **Education system**

The education system in Tanzania is also organized in stages just like the Nigeria education system. The documented education policy for Tanzania describes a 2-7-4-2-3 structure. There are two years

of pre-primary education for children below 5 years though attendance at this stage is not compulsory. The second and compulsory stage is the primary education which lasts for 7 years (Standard I – VII) after which the child may either enter work or proceed for 4 years of secondary ordinary level education during the ages 14-17 (Form 1-4). Students who pass the National Standard IV Exams can proceed for a further 2 years of advanced level to complete the secondary education cycle for ages 18-19 (Form 5 and 6). The last stage is the tertiary level stage where students spend 3 or more years depending on their choice of courses (Minister of Education and Culture, 2011).

Very recently the President of Tanzania has announced plans for considerable change in education policy (see, for example, Department for International Development, 2015). The changes include the extension of mandatory and free education for 4 more years and the increased use of Kiswahili (a native language in Tanzania) as the language of instruction at all levels. Among other changes, he also reaffirmed and extended the drive to build laboratories for secondary schools. These changes may affect the teaching of science subjects.

### **Mandatory Basic Education**

At present, the first seven years of primary education is mandatory in Tanzania for every child who has reached the age of seven years. At this stage of education, teaching and learning activities are done in Kiswahili in government primary schools. The primary school curriculum includes basic science and has the goals of developing: critical and creative thinking, communication, numeracy, technology literacy, personal and social life skills and independent learning (UNESCO, 2010).

Poneral et al. (2011) claimed that the elimination of primary school tuition fees in public schools in Tanzania led to massive enrolment of pupils in 2002. This claim was supported by a report from UNESCO which shows that the ending of primary tuition fees has led to a massive increase in the number of children enrolled in primary schools from 4.8 million in 2001 to 8.4 million in 2008 (UIS, 2010). Enrolment of girls is very close to parity with boys at all primary levels (Figure 3.10). However, many children who enroll in school drop-out before completing primary education

### **Secondary Education**

As already mentioned, Tanzanian Secondary education has two levels. Ordinary level runs from Form 1 through to Form 4 after which a certificate is issued to all passing the Certificate of Secondary Education Examinations. Students that pass well may progress to Advanced Level education (Forms 5 and 6) or study for an ordinary diploma in a technical college. During the course of the research visit, it was noted that there are only two (2) A level schools out of forty-nine (49) schools in the whole of Morogoro Municipal Region, which has population of 1200 students. This is an anecdotal indicator of

the fact that not all schools offer A Level classes. All students at this level are boarding students and, because of the potential social problems associated with boarding both male and female students, A-Level schools restrict enrolment to one sex.

The language of instruction in all secondary schools is a mixture of English and Kiswahili. The core subjects in Forms 1 to 4 offered by all schools includes physics with time allocations increasing from 8% to 10% of class time with level. The minimum number of subjects required for the Certificate of Secondary Education Examinations is seven and all candidates are tested in mathematics, English, Kiswahili, biology and civics. (UNESCO, 2010). Physics need not be included.

Most students study physics in Forms 1 and Form 2 but later drop the subject as it is perceived to be difficult – learners see the subject as too abstract.

The physics syllabus for Tanzania Certificate of Secondary Education (TCSE) stated the general aims of physics teaching to be;

- to understand the language of physics
- to explain theories, laws and principles of physics
- to understand the scientific method in solving problems
- to promote scientific and technological knowledge and skills in management, conservation and sustainable use of the environment
- to promote manipulative skills to manage various technological appliances
- to promote self-study for self-advancement in new frontiers of physics
- to appreciate the role of ICT in the process of learning (TCSE, 2009).

At Advanced Secondary level, physics may be studied as one of a package of three subjects comprising associated sciences or other subjects. Practical tests are a formal part of assessment (Ministry of Education and Vocational Training, 2013).

The official student-teacher ratio in Tanzania is 40 but there are shortages in maths and science (most especially in physics) as was evident during the research visit. Typically, there is one physics teacher who teaches the subject from Form 1 to Form 4 across the school. A report from the Prime Minister's Office in 2014 provides evidence of progression in key statistics (Tanzania Prime Minister's Office, 2014). Secondary enrolment increased from 1.22 M in 2008 to 1.80 M in 2013 and, over the same period, the pupil teacher ratios for primary and secondary schools fell from 53 and 37 respectively to 43 and 25.

**Table 3.5:** Enrolment and gender parity data for primary, secondary and tertiary education in Tanzania (Tanzania Prime Minister’s Office, 2014).

	<b>Pre school</b>	<b>School Education</b>			<b>HEIs</b>
		<b>Primary</b>	<b>Ordinary Secondary</b>	<b>Advanced Secondary</b>	
<b>Gross Enrolment Ratio</b>	32%	87%	32%		4%
<b>Gender Parity Index</b>		1.01	0.78		1.00
<b>Public enrolment (no. of institutions)</b>	970k	8,034k (5,600)	1,451k (3,500)	580k	144k (12)
<b>Private enrolment (no. of institutions)</b>	57k	198k (800)	278k (1000)	17k	75k (21)
<b>Total enrolment (no of institutions)</b>	1,026k	8,231k	1,729k	76k	219k (33)

Table 3.5 provides key education data for 2013. The most obvious issue is the very low enrolment at secondary levels and above. This is accompanied by a weakening of the gender parity index. The public sector dominates overall provision.

### **Tertiary Education**

Students who make the required grades in the Advanced Certificate of Secondary Education Examination ACSEE and receive a diploma after completing Form 6 may be selected to enrol in a University. There is no separate entrance examination in order to gain admission.

Presently, there are 33 universities which includes 12 public and 21 private institutions. In addition to this, Tanzania has 4 public and 11 private University colleges which provide programmes leading to degrees from other universities regulated by the Tanzania Commission for Universities (TCU, 2014)

Apart from the Universities in Tanzania, the Ministry of Education and Culture MOEC is currently overseeing a network of 34 Government Teacher Colleges and 14 registered privately owned ones. The Teacher Education Department of the Ministry is responsible for the provision of Teacher Education and it deals with preparation of grade ‘A’ and Diploma teachers to satisfy staffing needs for pre-school, primary and secondary education. (MOEC, 2014)

## **Funding**

Funding of education in Tanzania has been the sole responsibility of government. There were indications from the Education Sector Budget 2011/2012 that Tanzania had been spending between 17-20% of its total budget on education which is higher than the 5-7 % devoted to education in Nigeria. However, it was reported that there was a wide gap between the budgeted and spent fund as the Ministry spent only 76.8 billion shillings out of the 139.7 billion budgeted in the fiscal year 2010/2011 (HakiElimu, 2012). In the 2014/2015 budget, about 3,465 billion shillings which is around 17% of the total national budget of 19,853 billion shillings was spent on education (HakiElimu, 2014). However, the reason for the discrepancy between the budgeted and spent funds was not given.

## **3.4 Summary**

This chapter examines the social and educational context of countries visited in the study. The chapter revealed a rapid increasing population across countries in SSA, a result of the high birth rate across the continent. There were large differences in access to social amenities between rural and urban areas despite the fact that majority of the country's population are rural dwellers (Figure3.3).

Most of the SSA countries have had rapid growing economies but with limited science related employment except in South Africa. Despite the growing economy in SSA, the percentage of the government budget on education had not been able to meet the 26% educational target advocated by UNESCO. There has also been high rate of unemployment across the continent.

There have been dramatic increases in enrolment at all levels of education with a resultant effect of large class sizes at the primary, secondary and tertiary levels. Despite the increases in enrolment, there has been heavy drop out among students, mainly at the primary level in some SSA countries.

Physics is part of the teaching curriculum in most secondary schools in SSA with governments publishing specific objectives for teaching the subject but with limited allocated resources.

## CHAPTER 4

### METHODOLOGY AND PROTOCOL

#### 4.1 Introduction

This chapter describes the research method and procedures that were used to investigate and describe the status of practical physics in African schools. It comprises eight sections not counting this introduction. The first section deals with the research design which underpins the study and the rationales for adopting both quantitative and qualitative research methods. Sections two and three focus on the research instruments and the trustworthiness of those instruments. Sections four and five deals with ethical issues in the study and visit protocols. Sections six and seven outline the data collection and data analysis procedures. Finally, a summary of the chapter is presented in section eight

#### 4.2 Research Design

The research aims that were set out in Chapter 2 suggest a research design that includes both qualitative and quantitative approaches. In this section the benefits of each approach are introduced and the overall mixed mode design is then described

##### 4.2.1 Qualitative Methods

According to Berg and Lune (2011) qualitative methods *'help to provide answers to questions by examining various social settings and the views of individuals who inhabit the settings'*. Similar views have been set out by many others. According to Willis (2008), qualitative research enables the researcher to enter into other people's worlds and to understand, interpret and represent these peoples and their worlds. Qualitative research can capture the perspectives of the participants, how they interpret their experiences and how they structure their social world (Bogdan and Biklen, 2007; Willis, 2008). These authors describe qualitative research as a methodology where a small number of places, situations, or people are studied over a protracted period during which the researchers collect data through observation, participation, and interview. The consensus view is that this process allows researchers to share in the understandings and perceptions of others which themselves determine how people structure and give meaning to their daily lives.

Bogdan and Biklen (2007) discuss the immediacy of qualitative methods. They argue that *'if you want to understand the way people think about their world and how those definitions are formed, you need to get close to them, to hear them talk and observe them in their day-to-day lives'*.

Qualitative methodology explores the understanding of people from their own view point. Well conducted, it allows their voices to be heard and their reasons for particular activities and actions to be explored.

A common suggestion is that qualitative research emphasizes quality rather than quantity because data are collected in the field, rather than in more controlled situations (Bogdan and Biklen, 2007). Ogunmade (2005) quotes Miles and Huberman (1984) in arguing that qualitative methods have a quality of undeniableity, because they help to create concrete, vivid and meaningful descriptions of incidents and events. Direct testimony from stakeholders may be of particular value in encouraging action to follow from the very diverse study contained in this thesis. Of course, the process of gathering data from individuals can be protracted and time consuming and there are options for gathering personal views more efficiently. Thomas and Nelson (1996) suggest that focus group methods allow several people's views, perceptions and opinions to be gathered in one joint session. They argue too that the group dialogue can help in the filtering of extreme views and in the development of a better balanced view of the consensus opinion of the community.

Qualitative methods have formative value within the research. They can generate alternative explanations and enable the construction of a narrative history (Campbell, 1994). They help the researchers to reflect on the research in progress and provide opportunity for alteration in the research approach as the research proceeds (Bouma, 2000).

Qualitative methods have some disadvantages. They tend to produce large amounts of information that can only be focused after data collection. If a fully ethnographic approach is adopted (the systemic study of people and culture to explore cultural phenomena where the researcher observes society from the point of view of the subject of the study), there are no prior assumptions about which variables are relevant. The inquiry is open-ended and sensitive to the intentions, explanations and judgments of the participants (Bouma, 2000). It follows that systematic exploration of the data is a long process and a balanced understanding may be difficult to achieve. Conversely, if the agenda is defined too precisely, the data may not reflect divergent opinions.

The qualitative approach is used widely by educational researchers in journal publication, for example in 2008, in the *Journal of Research in Science Teaching*, 35.7% of its publications (63.9% in *Science Education* and 44.4% in the *International Journal of Science Education*) used a qualitative method for data collection (Devetak et al., 2010, cited in Vilaythong, 2011). Qualitative methods relies less on numbers and statistics but more on interviews, observations and small numbers of questionnaires, focus groups, subjective report and case studies. These data emphasize the interpretation and meaning attached to experience (Searle, 1999, cited in Vilathong, 2011).



### **4.2.2 Quantitative Methods**

Quantitative research is very different – it tends to be more statistically based and make much more use of numerical data (Denscombe, 2007, p.248). Quantitative data collection involves defining and measuring so-called variables and, usually, determining the relationships between them. These variables may be associated with demographics or with opinions. Bouma (2002) has framed the value of quantitative methods in terms of helping to identify and assess the knowledge of respondents and assess their attitudes, values, beliefs or opinions.

A crucial feature of quantitative methods is that they involve prior structuring of the inquiry. House (1994) indicates that questionnaires in quantitative research give more precise, explicit and predetermined measure and identification of variables that have been pre-defined. Hollingsworth and Hackling (in press), make the claim that questionnaires are economical and very simple to administer, and ensure efficient gathering of large quantities of baseline data. The responses gathered can usually be transformed easily by coding into data files that are amenable to statistical analysis. However, useful and insightful questionnaires are difficult and complex to construct and their success depends on the honesty of the respondents (Bouma, 2000). A key issue is how respondents understand the questions and options they are faced with and the expectations that are involved in responding. Comparisons across cultural boundaries are particularly problematic.

Berg (1998) has suggested that, despite the complexity of quantitative methods, they are more quickly accomplished, produce more reliable conclusions and help provide reportable findings, involving percentages of variable occurrences. Patton (1990) concludes that quantitative methods are essential in educational research because it makes it possible to measure the reactions of great many people to a limited set of questions.

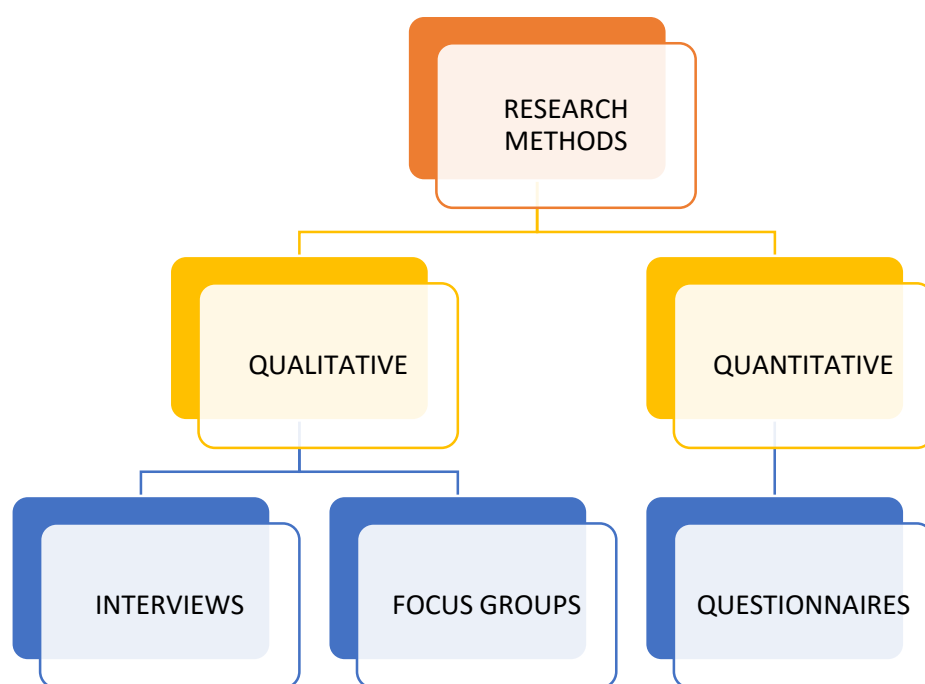
Leaving aside the academic research arguments for quantitative approaches, there is a pragmatic reason why they are essential to this study. It is hoped that the thesis will be of interest to a scientific community that is accustomed to seeking answers to research questions using measurement and quantitative analysis. The community is more likely to be influenced by data with which they are comfortable and that means that quantitative approaches must be part of the design portfolio.

### **4.2.3 Overall Mixed Mode Design**

Research has shown that if a study uses different research methods, for example qualitative and quantitative, it has the advantages of helping the researcher to gain a deeper understanding of certain issues pertaining to the problem under investigation (Taylor, 2004; Ogunmade, 2005; Cohen

et al., 2007). While qualitative and quantitative methods can each gather valuable information on their own, findings from the two approaches are distinct and complementary (Berg, 1998). According to Neumann (2003) the combination of qualitative and qualitative data gathering techniques is advantageous and good research practice in that it “often combine the features of each” enabling a confirmation or corroboration of each other through triangulation. Yet the key features of the qualitative methods can be seen when contrasted with quantitative methods (Cossa, 2007)

The use of multiple data sources and cross comparisons to gain understanding of a phenomenon ensures trustworthiness and credibility of interpretation of data collected (Creswell, 2007; Buabeng, 2015). Basically, no single approach, qualitative or quantitative, can be perfectly effective and so each method can be improved significantly through triangulation of data from various approaches and sources (Yin, 2003; Ogunmade, 2005). A mixed approach is relevant to this study which will triangulate and corroborate findings from teachers, students and other stakeholders. It will enable the researcher to get a more holistic picture of the answers to the research questions as well as gain deeper insight into the teaching and learning of practical physics in secondary schools in SSA.



**Figure 4.1:** Research Design.

Figure 4.1 summarizes the mixed mode approach used in this thesis. It should be remembered that the research questions are concerned with practical physics teaching in (Sub-Saharan) Africa. Obviously, data gathering from across a diverse continent is not possible and, therefore, a case study approach has been used involving data gathering during short visits to a small but diverse set of

countries. Background data on Sub-Saharan Africa has been gathered using desk research. The diversity of opinion has been tested through qualitative approaches. For pragmatic reasons these have been structured while allowing a degree of more open input. Comparative data on a limited set of issues suggested by previous research has been gathered using quantitative methods. The mixed method approach allows corroboration of the findings.

The qualitative evidence gathering took the form of structured interviews and focus groups involving a range of stakeholders; physics teachers and students, school principals and officials including lecturers, inspectors and examiners. There was also a structured discussion with Institute of Physics volunteer coordinators who are heavily involved in the development of the practical physics curriculum across Africa. The interviews were done to investigate qualitatively, and delve deeper into issues that were not completely resolved by the questionnaires (Fraenkel et al, 2012; Buabeng, 2015). The stakeholder's interviews were intended to provide a national perspective and to elicit direct information about their experiences, knowledge and opinions concerning the teaching and learning of practical physics in secondary schools

The quantitative data gathering involved two short surveys. A teacher survey helped to identify; the delivery of the practical physics curriculum, the teaching and assessment methods in secondary physics, and the factors limiting and acting as a barrier to change. A student survey helped further in gathering student views about their interest in physics, their perception of the aims of practical work, their own competency and attitudes to practical physics.

Securing permissions to visit countries and schools and interview or survey stakeholders was difficult and the research was carried out opportunistically.

In the next section the research instruments are discussed.

### **4.3 Research Instruments**

The main research instruments used for data collection in this study were; teacher and student questionnaires, focus group meetings and interview protocols. In this section we examine each class of instrument in turn.

#### **4.3.1 Survey Questionnaires**

Two forms of survey were used for data collection; a teacher survey and a student survey. In the development of the questionnaires, particular attention was given to ensure that questions were as suggested by May (2001), i.e. unambiguous, unbiased, unloaded, relevant, succinctly conceptualized

and avoiding vagueness (May, 2001). In particular, care was taken to ensure questions were appropriate for the culture and context of Africa.

### **Teacher Survey (Appendix A)**

The teacher questionnaire comprised seven sections. The first section elicited information on demographic data regarding the teacher's age, qualifications, years of teaching experience, area of teaching specialization, class size and school location. The second section focused on the availability of resources and facilities in the school. Section three examined the level of assessment the teacher used in the teaching and learning of physics. Section four looked at current practice. Section five examined the approaches used by teachers in teaching of practical physics. Section six focused on aims and the final section examined both the obstacles that affect the teaching and learning of practical physics and how the teaching could be improved. The two final sections provided opportunities for the teachers to add free responses.

### **Student Survey (Appendix B)**

The purpose of the student survey was to investigate students' perceptions about practical physics teaching and learning in secondary schools in Africa. The questionnaire comprised three sections. The first section asked for demographic data, including the type of school (boys/girls/co-education) and its location, the year/level of the student, and their gender. Section two elicited the student's views about teaching and learning activities in their physics classroom and the attitude of the student to the teaching and learning of practical physics in their school. The questionnaire included open-ended questions in which students were asked to write answers describing what they most enjoy and least enjoy about practical activities in their physics lesson and what might be done to help them learn more about practical physics in their school.

### **4.3.2 Focus Groups**

The purpose of the focus groups was to gather relevant data from the learning stakeholders (students) in physics education, to understand the current practice in practical physics teaching and to investigate their perceptions on the quality of practical physics teaching and learning in their school.

This study involved sixteen (16) focus group meetings with students between 15 to 18 years. Five of the focus groups were conducted in Nigeria, three in Ghana, four in South Africa and four in Tanzania. Each took place in a school setting. There were 5 to 8 participants in each of the focus group meetings as indicated in Table 4.1. The meetings addressed the following questions.

1. What do you do in your practical physics classes?
2. What sort of things are you trying to learn?
3. Do you like studying practical physics?
4. How well are you and your lab partner doing?
5. What is the best practical physics session you have had?
6. What would your ideal practical physics session look like?

To achieve rich and constructive discussions during the focus group meetings, the students were provided with focus questions to afford them the opportunity to discuss them with their colleagues and to bring with them well constructed and broadly representative views before the commencement of the meetings. The leaders of each group were brought together to discuss each of the six questions together with issues that arose during the discussion. The whole group discussions were audio recorded by the researcher. Each focus group meeting and discussion lasted for about two hours.

#### **4.3.3 Interview Protocols (Appendix C)**

To gain a broader national and international perspective, interviews were also conducted with other key stakeholders in physics education in Africa. These included physics curriculum officers in ministries of education, physics lecturers from both teacher training colleges and universities, practical physics examiners, science/physics teachers, school principals/school heads and policy makers from the ministries of education. The semi-structured interview protocols were designed to gather data in the participants' own words so that greater insight could be gained about the teaching and learning process (Fraenkel et al., 2012). The semi-structured interview is suitable for probing views and opinions and permits respondents to develop and expand on their own responses. Further questions which were not expected at the commencement of the interview could also be asked as new issues arose. (Gray, 2009). The participants responded to semi-structured interviews which were centred on the main research question formulated to guide the study. The issue of validity for both structured and semi-structured interviews is addressed by ensuring that questions are related to the research objectives (Cohen et al., 2007; Gray, 2009). The semi-structured interview protocols for the teachers, students and other stakeholders are provided in Appendix C. The interviewees were provided with focus questions to afford them the opportunity to think about

their responses before the commencement of the interviews, this created room for rich and constructive discussion.

#### **4.4 Rigor and Trustworthiness of the Instruments**

According to Punch (1999, cited in Ogunmade (2005)), an instrument is considered valid when there is confidence that it measures what it is intended to measure in a given situation. If the rigor and trustworthiness of a study are not ensured, then the validity and reliability of the study will be questionable and the aim of the study will not be met. Hence, there is a need for the researcher to ensure the rigour and trustworthiness of the methods used in the study (Banu, 2011). Meriwether (2001) has commented on the value of pilot testing of instruments to reduce the ambiguity of item and enhance reliability.

Bearing this in mind, the survey questionnaires and interviews were pilot tested with physics teachers and students from two secondary schools in a local education district in Ekiti State, Nigeria. These schools were not associated with the study in any way. Although Nigeria was not originally intended to be one of the countries involved in the study, it was a convenient location in which to test the qualitative instruments developed. The objectives of this pilot study were to determine the clarity, relevance and effectiveness of the questions in eliciting information from the two groups of participants. In addition, piloting provided an opportunity to practice interviewing skills and identify any practical issues that might arise in the main study.

The interview guides for the pilot study were gradually developed through informal discussion and validated by simulated interviews with my supervisors and some colleagues.

The pilot study interviews were conducted with five types of key stakeholder in physics education including a school inspector, chief examiner in practical physics and a team leader in practical physics, school principals, physics teachers and the students. Face to face interviews were held, notes taken and the conversations recorded. Before the interviews, all the interviewees were asked to give permission for recording. The interview questions for the physics teachers and other staff were focused on the objectives of teaching practical physics in schools. The interview questions for the students were focused on students' reasons for studying physics and the problems affecting their studies. The durations of the interviews were on average about twenty minutes for the stakeholders and ten minutes for each student. All informants were aware of the anonymous treatment of their answers.

Following the pilot study, minor changes in wording were made to the surveys. The most significant changes were to the questions on aims and qualification requirements where physics teachers were

asked to tick which of five listed aims/qualification requirements were most important. Most eventually put a tick to all the listed items. The survey instrument was modified to ask the teachers to rank the items in order of importance, allowing enhanced information on teacher priorities.

In addition, the interview scripts were modified to identify follow up questions that could be used to prompt or elaborate responses from stakeholders.

## **4.5 Ethical Issues in the Study**

In research, ethical matters are the principles of right and wrong, acceptable by a particular group at a particular time (Bogdan and Biklen, 2007). According to Glense and Peshkin (1993), ethical codes represent desires and efforts to show respect to others' rights, to carry out responsibilities, avoid harm, and supplement benefits to the subjects. Glesne and Peshkin asserted further that ethical codes deal with individual rights to dignity, privacy, confidentiality and avoidance of harm. In this study, two main ethical guidelines were paramount:

- a. Participants should enter the study voluntarily, knowing the nature of the study and possible dangers and obligation involved in the study, and
- b. Participants should not be exposed to any risk, which is greater than the gain they might derive from participation (Bogdan and Biklen, 2007).

If the ethical issues are neglected while doing a study, the study will be questionable and the subjects of the study may face risks or their rights may be dishonored. Since ethical issues are the responsibility of the researchers to the public, the discipline, sponsors, researcher's own government and the host government (Glense and Peshkin, 1993), researchers need to take care to follow ethical guidelines.

Ethical approval for the research in this thesis was sought and obtained from the Human Research Ethics Committee (HREC) of the Open University, Walton Hall Milton Keynes, United Kingdom (Appendix D). As the participants in the study were from different countries in Africa, ethical approval was also sought from the Ministry of Education in each country. In addition, written informed consent was sought from the head teachers of each school and the science/physics teachers who were to be participants in the study. All participants were reassured that there was no personal risk associated with participation in the study, and that they would be free to withdraw from the study at any time without penalty.

Confidentiality was a key ethical issue as, in several of the societies explored, there is a culture of deference to authority. Challenge may have been problematic for some participants. Confidentiality was adhered to throughout the study. Teachers and students were asked not to write any form of identification on the questionnaire. Before the interviews and focus groups the researcher assured them that their names would not be used without their permission. Where necessary, pseudonyms would be used in any publication. In addition, care would be taken to ensure that indirect identification would not be possible from settings or other ancillary information.

Focus group meetings and interviews were conducted at times suitable for the participants. Care was taken to be respectful of local culture, including the normal modes of conversation and discourse in that country. The researcher and the accompanying supervisor on the research visits were Nigerians and this may have helped in minimizing the sense of shared experience and in creating empathy during conversations.

#### **4.6 Research Visits— Location and Participants**

The study was conducted in four countries in Africa: Ghana, South Africa, Nigeria and Tanzania with an estimated total population of about 340 million people. Permission to conduct the research in Ethiopia was withdrawn immediately prior to an intended visit. This visit still took place but without any research output other than that available from participant inquiry. The visits to the four countries took place between July 2014 and July 2015 with three of the four visits scheduled to coincide with practical physics workshops being organised by Institute of Physics (IoP) volunteer coordinators. The Nigerian visit was organised by the researcher without such support – the researcher is a Nigerian and is familiar with the geopolitical and social issues in the country.

A critical issue in pursuing this study was the choice of schools to visit and participants to interview/survey. The countries to visit were chosen from those in which the IoP was involved through an existing Practical Physics initiative. In these countries there was a core of committed contacts who might be expected to facilitate the research. The countries chosen spanned Sub-Saharan Africa and included countries with different levels of economic development.

Summary information on the schools visited is provided in Table 4.1. Each school was identified by a code letter. More detail about the schools and their selection is provided below and in Chapter 5.



**Table 4.1:** Summary of schools selection and settings

School Code	Location	Total School Enrolment	Total Physics Enrolment	Type of School	Number of Physics Teachers	Boys Participants	Girls Participants
School A	Sub-Urban	1300	299	Mixed	2	25	22
School B	Urban	1000	300	Boys	2	31	—
School C	Rural	2000	290	Mixed	3	15	7
School D	Sub-Urban	531	60	Mixed	—	7	11
School E	Rural	700	136	Mixed	2	7	17
School F	Urban	1000	75	Mixed	1	13	11
School G	Sub-Urban	1000	1000	Mixed	3	33	36
School H	Urban	560	560	Mixed	2	15	26
School I	Rural	1200	340	Mixed	3	11	13
School J	Sub-Urban	635	115	Mixed	1	11	17
School K	Rural	403	79	Mixed	1	4	11
School L	Urban	450	70	Boys	1	22	—
School M	Urban	250	95	Girls	1	—	18
School N	Rural	350	60	Mixed	1	11	6
School O	Rural	281	80	Mixed	1	11	15
School P	Urban	700	33	Mixed	1	4	4
School Q	Urban	567	303	Girls	5	—	84
School R	Urban	546	104	Mixed	1	11	21

Purposive and opportunistic sampling was used to choose the schools and participants in the study. The aim was to identify people who would be highly motivated to participate in the study and would provide insights from valuable and differing perspectives. Preliminary conversations with local contacts helped to identify possible participants and, in some cases, those same contacts were able to facilitate cooperation.

A major issue in arranging school visits related to access and the ever growing security within schools. However, by allowing opportunistic sampling, schools could be chosen through acquaintance between contacts and school head teachers. This led to a relatively open selection of schools across the four different countries. The schools that were visited were broadly representative of high schools in the four countries in terms of size and geographical setting and could be regarded as comprising a '*naturalistic coverage*' (Ball, 1984). All schools were approached by telephone and permission/access confirmed via email. Eighteen (18) schools allowed access and

agreed to participate in the main study - Ghana (Schools A to C); South Africa (Schools D to I), Nigeria (Schools J to N), and Tanzania (Schools O to R).

Approximately 550 Students from the 18 schools in four countries participated in the study (Table 4.2). The school types were 71% co-educational, 9% boys only, 20% girls only. Eight (40%) of the schools were situated in urban locations, 37% in suburban locations and 19% in rural locations. The students who participated were approximately representative of the population of students in the eighteen secondary schools across the four countries.

**Table 4.2:** The sample frame for the student's survey

School type	School Location						Total
	Urban (44%)		Suburban (37%)		Rural (19%)		
	male	female	male	female	male	female	
Coeducational	43	62	85	100	49	53	392 (71%)
Boys only	31	0	18	0	0	0	49 (9%)
Girls only	0	109	0	0	0	0	109 (20%)
Total	74	171	103	100	49	53	550
Total	245		203		102		550

The study also surveyed and interviewed 44 physics teachers. Also interviewed in the study were a number of science teachers, school principals, curriculum officers, Heads of Science departments, practical physics examiners, senior officials from Ministries of Education, IoP volunteer coordinators, a Director of a National Science Resource Centre (NSRC) and physics lecturers, from universities and Teacher Training Colleges (TTC). The breakdown of participants from the four countries is shown in Table 4.3.

**Table 4.3:** Sample frame for the participants interviewed

	<b>Ghana</b>	<b>South Africa</b>	<b>Nigeria</b>	<b>Tanzania</b>
<b>Stakeholder</b>				
<b>Science Teachers</b>	–	–	–	3
<b>Physics Teachers</b>	7	10	5	6
<b>Physics students</b>	20	18	16	26
<b>Heads of Science Departments</b>	3	5	3	1
<b>School Heads</b>	3	4	3	2
<b>Curriculum officers</b>	3	1	–	–
<b>Directors from Ministry of Education</b>	3	1	–	1
<b>School Inspectors</b>	–	–	1	–
<b>Practical Physics Examiners</b>	–	–	2	–
<b>Physics Lecturers</b>	2	5	2	3
<b>Laboratory Technicians</b>	–	–	–	2
<b>IoP volunteer coordinators</b>	1	1	–	2
<b>Total</b>	42	45	32	46

It is worth noting that the contribution of the key stakeholders is crucial to this study because of their roles in physics education in Sub-Saharan Africa. This study involves the curriculum definition stakeholders, curriculum delivery stakeholders and the learner stakeholders. Their functions include:

- I. The curriculum-definition stakeholders define or influence strongly the national and state definition of the practical physics curriculum. They also define what is formally required for success and project models of acceptable good practices.
- II. The curriculum-delivery stakeholders help to interpret the schools' responses to the national requirement, allocate resources and influence teachers' priorities. They deliver the curriculum and set expectations for teachers with respect to their professional roles.
- III. Learner stakeholders respond to the approaches offered and influence what is believed to be pedagogically achievable.

Stakeholders and individuals may have influence in more than one of the above categories. The allocation is chosen to reflect core influence. In addition to the above there are NGOs who have

influence, notably the Institute of Physics (IoP), the United Nations Educational Scientific and Cultural Organization (UNESCO), major charities etc. These work with stakeholders at each of the above levels.

In the following sub-sections greater detail will be provided about the schools and participants in each of the countries.

#### **4.6.1 Practical Arrangements — Ghana**

Email exchanges between the researcher and the Director of Secondary Education at the Ministry of Education as well as the Director of the National Science Resource Centre, both in Accra, led to permission to access their schools. The researcher later liaised with the IoP National Coordinator (Ghana) in locating three schools in rural, suburban and urban environments (Schools A to C). These were in Accra, the capital city, Cape Coast (a coastal suburban area) and Ada which is rural though not remote. All these sites are in the South of the country. It was not possible to visit the more remote North. Information letters, and consent forms (Appendices E, F and G) were sent to Head teachers and relevant teachers. The letter included information about the aims and significance of the study and solicited necessary permissions. After gaining the consents, the visit to Ghana was scheduled and took place between 14<sup>th</sup> July 2014 and 19<sup>th</sup> July 2014.

School A is a suburban high school located within university premises. The school has around 1300 students on roll from age eleven to seventeen all of mixed ability with about 23 percent taking physics as a separate subject. The school has two physics teachers to cater for the approximately 299 students taking physics from form one to form three.

School B is in the capital city with a student population of 1000. It is a government funded boys' school and has 300 students taking physics from Form one to Form three with a physics teacher who teaches the 300 students.

School C is a rural high school which accommodates students from nearly all the districts in the Ghana. It has around 2000 students on roll from age eleven to seventeen, all of mixed ability, with about 290 students taking physics as a separate subject. The school has three young physics teachers. The science departments in the three schools follow the Ghana National Physics Curriculum and the students are studying for the West Africa Examination Council Certificate whose exam is normally held between May and June of every year. About 71 male students and 29 female students participated in the study from the three schools. 29 of these students took part in focus group discussions.

About 22 non-student stakeholders participated in the study in Ghana. These included: seven physics teacher from the three schools involved in the survey (two from School A, two from School B and three from school C). The school principals of the three schools and the heads of science departments were interviewed. The researcher also interviewed the Director in charge of Secondary Education in the Ministry of Education, two Directors from the National Science Resource Centre, which is based in Accra, and the three curriculum officers for mathematics, chemistry and physics. Two teacher trainers from the Ada Teacher Training Colleges and the IoP national coordinator also participated in the study.



**Photo 4.1:** Unused physics equipment in one of the schools in Ghana

During the visit to Ghana, there was an opportunity to record a clear example of the unused practical physics resources that are commented on later in this thesis (Photo 4.1). These equipment were meant to be used during the day-to-day teaching and learning activities in physics but were kept unused in the store room and only brought out for examination purposes.

#### **4.6.2 Practical Arrangements — South Africa**

The practical arrangements followed the pattern for Ghana though, in this case, the locations visited were well separated and an internal flight was necessary. Following extensive discussion, visits were arranged to schools in Soweto (School D which is a mixed school located at the city centre and school G, a science school located within a university campus which is a short distance away from school D), Pretoria (School E is located in a remote area which is about 2 hours from Pretoria), Johannesburg (School F which is a very big school located at the centre of the city) and Cape Town (School H located within the city and School I located in the most remote area of Cape Town). Both Schools D and G are located within the Gauteng Province while Schools H and I are located within

the Western Cape Province. For this visit, permission (Appendix H) was sought and obtained from the Western Cape Ministry of Education for collecting the data for the study in the Western Cape Province. The visit took place between Jan 19<sup>th</sup> 2015 and Jan 29<sup>th</sup> 2015.

School D is a suburban secondary school located at the centre of a city in Gauteng provinces. The school has around 531 students on roll from age eleven to seventeen all of mixed ability with 11 percent (60) offering physical science as a separate subject. Unfortunately, the principal of the school doubled as the physics teacher due to lack of a physics teacher to teach the students from Grade 9 to Grade 12. About 18 students (7 boys and 11 girls) in Grade 12 participated in the study from school D.

School E is situated in the rural area of the administrative capital of the country. This is a school that has been battling with theft of science equipment and poor matriculation results for a decade. It has around 700 students on roll from age eleven to seventeen all of mixed ability and about 136 students take physics as a separate subject. The schools has two (2) physics teachers. About 24 students (7 boys and 17 girls) in grade 12 participated in the study.

School F is at the centre of another big city in Gauteng province. The school has around 1000 students on roll from age eleven to seventeen all of mixed ability and about 75 students take physics as a separate subject from Grade 10 to Grade 12. The school has one teacher who teaches physics alongside health education in all the grades. About 24 students (13 boys and 11 girls) in Grade 12 participated in the study.

School G is a special school located within a university campus, basically for science students from Grade 10 to Grade 12. It has around 1000 students on roll from ages fourteen to seventeen all of mixed ability and all the students take physics as a separate subject. The school has three physics teachers. A total of 69 students (36 females and 33 male) from Grade 12 participated in the study.

School H is an urban secondary school from the Western Cape Province. It is a school established for the purpose of improving the quality of science and mathematics within the province. It has around 560 students on roll from age eleven to seventeen all of mixed ability and all of the students take physics as a separate subject from Grade 8 to Grade 12. The school has two physics specialist teachers. About 41 students (15 boys and 26 girls) participated in the study.

School I is a rural high school in the Western Cape Province. It has around 1200 students on roll from age eleven to seventeen all of mixed ability and about 340 students take physics as a separate subject. There are three physics teachers in the school. About 24 students (11 boys and 13 girls) from Grade 12 participated in the study.

The science departments of the six schools follow the South Africa National Secondary School Physics Curriculum as the students are studying for the National Certificate Examination, also known as the 'Matric' examination.

The South Africa research visit engaged about 24 stakeholders from both the Gauteng and Western Cape provinces. There were 10 physical science teachers. The school principal and the heads of the science departments of the six schools also participated, as did the director of the science centre in Soweto, who is a physics professor from the University of Johannesburg, and his counterpart from the South Africa Institute of Physics, who is also lectures in the same university. Three physics lecturers, a female professor of physics from the University of Pretoria, a reader from the Department of Physics of from the University of Johannesburg and a professor from the University of Cape Town who is also the director of the school development unit all participated in the study. Also involved in the study is the director in charge of curriculum improvement from the Western Cape Ministry of Education.

The student survey involved 200 students from 6 schools and 25 students who participated in the focus group discussions were interviewed.

#### **4.6.3 Practical Arrangements — Nigeria**

Finding participants for the research activities in Nigeria was quite an easy task for the researcher due to the fact that he is based in Nigeria and has easy access to schools. Participants were invited from two states in the South-Western part of Nigeria where education is seen as a priority. Emails were also sent to two other schools, one in the South-Eastern part and the other in the North-Central part of Nigeria. Attempts to include schools in the North-Eastern part of Nigeria were frustrated by the activities of insurgents which have led to the closure of some schools in the area to safeguard the students from Boko-Haram attack. Consents were sought via email and telephone conversations with the school principals and other stakeholders, having informed them about the details of the research work. The schedules for the visits were arranged after they had all agreed to take part in the study. The visits took place between 19<sup>th</sup> of March 2015 and 26<sup>th</sup> of March 2015.

Participants in Nigeria were drawn from the three main geopolitical zones. Participants were from two states in the South West, a state in the East and another state in the North. Five schools were invited to participate in the study. Two of the schools were in Ekiti state, one in Ondo state all in the South West, one from a state in the East and a school from Taraba state in the northern part of the country.

School J is a suburban government college in a state in the South-Western part of the country. The school has around 635 students on roll from age eleven to seventeen, all of mixed ability with 18 percent (115) taking physics as a separate subject from Grade 10 to 12. The school has one physics teacher. About 28 students (11 boys and 17 girls) of Grade 12 participated in this study.

School K is to the North of school J and is situated in the rural area of the state. The school has around 403 students on roll from age eleven to seventeen, all of mixed ability with about 79 students taking physics as a separate subject. The school has one physics teacher and 15 students (4 boys and 11 girls) from Grade 12 participated in the study.

School L is an urban secondary school in another state in the South-Western part of the country. The school has around 450 students on rolls from age eleven to seventeen all boys. There were 70 students from Grade 10 to Grade 12 taking physics as a separate subject. The school has one physics teacher and about 22 boys participated in the school.

School M is located in a business city in the Eastern part of the country. The school has around 250 students on roll from age eleven to seventeen all girls with 20 percent (95) taking physics as a separate subject. The school has one physics teacher, and 18 girls in Grade 12 participated in the study.

School N is a rural secondary school located in the Northern part of the country. The school has around 350 students on roll from age eleven to seventeen all of mixed ability with 17 percent (60) students taking physics as a separate subject. The school has one physics teacher, and 17 students (11 boys and 6 girls) participated in this study. All the schools follow the Nigeria National Physics Curriculum as the students are studying for the West Africa Examination Council Certificate which is normally held between May and June each year.

Five (5) physics teachers and three (3) heads of science departments from the schools involved participated in the study. Also three school principals and two practical physics examiners were interviewed. A director from the school inspectorate unit of the ministry of education who is also an expert in physics education consented to participate. Two physics lecturers, one from Obafemi Awolowo University, Ile Ife and the other from the College of Education in Ikere-Ekiti were part of the study. About 100 students participated in the study while 20 who participated in the focus group discussions were interviewed.





**Photo 4.2:** A typical physics laboratory



**Photo 4.3:** A typical store room

Photos 4.2 and 4.3 show a typical physics lab and store room, both in Nigeria but typical across all countries visited. It is clear that there is a lack of maintenance and orderly management of resources. This might be as a result of the lack of laboratory assistant support which is commented on later in the thesis.

#### **4.6.4 Practical Arrangement — Tanzania**

Inviting participation in the research study was facilitated by the IoP volunteer coordinator and the national coordinator for Tanzania. Permission was sought by email from the Director of Secondary Education at the Morogoro municipality for the conduct of the study. Information letters were also

sent to the school heads in the region seeking access to their students and to their physics teachers with detailed information on the aim and significance of the study. After gaining consent to carry out the study in the region, the schedule of the visit was arranged to coincide with the IoP Practical Physics workshop for physics teachers taking place at the Teachers Training College in Morogoro and Mvomero region. The visits took place between 11<sup>th</sup> of July 2015 and 19<sup>th</sup> of July 2015.

Participants for this study in Tanzania were drawn from two main locations - the Mvomero and Morogoro regions. Four schools agreed to participate in the study. One of the schools is from Mvomero region which is a rural part of Tanzania and the other three schools were from Morogoro region which is an urban area.

School O is a rural secondary school located in Mvomero region of the country. The school has around 281 students on roll, aged from eleven to seventeen, all of mixed ability. There are 80 students taking physics as a separate subject, and the school has one physics teacher. About 26 students (11 boys and 15 girls) from form IV participated in the study.

School P is located in the urban area of Morogoro municipal. It is a school within a university campus. The school has around 700 students on the roll, from age eleven to seventeen, all of mixed ability with only 5% (33) students taking physics as a separate subject. The school has one physics teacher. About 8 students (4 boys and 4 girls) from form IV participated in the study.

School Q is a girl's school within the Morogoro municipal which has around 567 students all girls. There are 303 students taking physics as a separate subject, and five specialist physics teachers. A total of 84 students, all girls in form VI, participated in the study.

School R which is the last school is located to the South of school Q. The school has around 546 students on roll, aged eleven to seventeen, all of mixed ability. There are 104 students from Form I to Form IV taking physics as a separate subject. The school has one physics teacher while about 32 students (21 girls and 11 boys) from Form IV participated in the study. The science department in the four schools follows the Tanzania National Physics Curriculum and the students are studying for the Advanced Certificate of Secondary Education (ACSE).

There were six (6) physics teachers, 2 chemistry teachers and one biology teachers who participated. There were also two head teachers and one head of a science department who were involved. The director in charge of secondary education from the Ministry of Education in Morogoro gave his consent to participate in the study. Three physics lecturers; two from Morogoro Teacher Training College and one from the University of Dar es Salaam were part of the study, and the laboratory technicians from both institutions also participated in the study. The Institute of Physics volunteer

coordinator and the National Conductor who is also a national trainer were part of the study. About 150 students were surveyed in the four schools while 25 of them were interviewed from the focus groups.



**Photo 4.4:** One of the schools visited in Tanzania.



**Photo 4.5:** A laboratory for physics, chemistry and biology in a school in Tanzania.

Photos 4.4 and 4.5 were taken in one of the Tanzanian schools visited in this study. The laboratory is used for all the science subjects. As with earlier photos, there is evidence of limited oversight and organisation of resources.

## 4.7 Procedure for Data Collection

Data collection for this research study was divided into four phases. These have been discussed above but the process is drawn together here for convenience.

Phase 1 - Pilot testing of the research instruments as described above. The main aim of the pilot study was to trial the method for use in the main study. The findings from the pilot study highlighted the areas where the questionnaires could be improved and modified to further benefit the main study. Based on the responses in the survey questionnaires and comments from the interviews, corrections and improvements were made to the research instruments. The modification to the instruments was done in consultation with my supervisors after which they were considered appropriate for the main research study.

Phase 2- Distribution and administration of questionnaires. Teacher survey questionnaires were distributed to physics teachers in the senior high schools in each of the countries that were involved in the study. Also, the student survey questionnaires were distributed to teachers of the sample schools. To ensure a high return rate of the questionnaires, the researcher personally supervised the distribution and collection from teachers and students. All of the teachers completed the questionnaires within the visit period and returned the questionnaires for analysis. The return rate was 100% for the teacher survey. A 100% return rate was also achieved for the student survey, since the students were asked to respond to the questionnaires during class time. The administration of the student questionnaires was personally supervised by the researcher.

Phase 3 - Focus group meetings. Seventeen focus groups meetings were conducted by the researcher with the students in the four countries visited.

Phase 4 - Interviews. The final phase of the field based research data collection involved interviews with the various stakeholders which included: physics teachers, school heads, curriculum officers, heads of science departments, officials from Ministries of Education, physics educators from the universities and colleges of education, and Institute of Physics (IoP) volunteer coordinators.

A letter of invitation stating the purpose of the study was sent to key stakeholders via email in the countries involved in the study to seek their consent to participate in the interviews. Interviews were conducted face to face during the research visits with participants who had indicated their willingness to participate. Interviews were audio recorded by the researcher and lasted for about 30 minutes with each stakeholder.

Also, a small focus group discussion was held at the Institute of Physics (IoP) with stakeholders who are volunteer coordinators for the IoP in Africa. This focus group discussion was based around the identification of influences on the present status of practical physics teaching in Africa.

## **4.8 Procedure for Data Analysis**

### **Data Analysis**

The research data collected were extensive and as such were analysed using both quantitative and qualitative methods. Patton (1990) notes, *'the analysis of the empirical data aims to make sense of massive amounts of data, reduce the volume of information, identify significant patterns, and construct a framework for communicating the essence of what the data reveals'* (p.371-372).

### **Questionnaires**

Data from the teacher and student questionnaires were analysed using descriptive statistical methods involving percentages, means and standard deviations where appropriate. Responses to open-ended questions were coded into categories and the frequencies of teachers' and students' responses in each category were determined. Responses on the item scale were also coded in relation to the items so that the number and percentage that responded "all the time", "most of the time", "sometime", "not often" and "never" were calculated using the SPSS 13.0 statistical package.

### **Focus groups and Interview**

The audio recordings from the focus group discussions with the students and other stakeholders' interviews were listened to several times by the researcher and transcribed verbatim. Nvivo Pro 11 version for windows (QSR International Pty Ltd) was used to organise the materials by coding them into nodes which provided easy retrieval of the themes that emerged. Where quotes are used within the body of the thesis, they were chosen because they were representative of the statements of most of the respondents. The production of accurate and verbatim transcripts was integral to establishing the credibility and trustworthiness of the data.

## **4.9 Summary**

The study was designed with the aim of investigating the present practice in the teaching and learning of practical physics in African schools with a view to improvements. The summary of the research design used in this study is outlined in Figure 4.1 in this chapter. A mixed method approach of both qualitative and quantitative methods were employed to achieve the aims of this study.

These methods included the survey of both the physics teachers and their students, focus group discussions with the students and interviews with physics teachers and other relevant stakeholders in physics education. The sample of this study consist of 550 secondary school students with an average age of 17 years, 44 physics teachers and 57 relevant stakeholders. The study took place in four countries in Africa between July 2014 and July 2015.

This chapter described also the development of the research instruments including piloting the instruments, rigor and trustworthiness, ethical issues, data collection procedure and methods of data analysis. In the Table 4.4 below, a summary of data sources which address each of the research question for the study is presented.

**Table 4.4:** Data source relationships to the research questions.

Data sources	Research Question			
	1	2	3	4
Teacher questionnaires	✓	✓	✓	✓
Student questionnaires	✓	✓		
Focus groups	✓	✓	✓	✓
Interviews	✓	✓	✓	✓

## **CHAPTER 5**

### **QUANTITATIVE RESULTS**

#### **5.1 Introduction**

This chapter provides the results of the surveys carried out on teachers and students in the four Sub-Saharan African countries where data gathering took place. As already discussed, Sub-Saharan Africa is very diverse, and the four countries visited span different levels of economic development and varied social attitudes. The data gathered can help to identify issues and views that can be correlated with qualitative data. It can inform later discussion of present practice and may guide future interventions.

The overall structure is similar to that of Chapter 3 which describes the four countries at an overall level and then highlights specific issues for each country.

In the next section, there is a brief account of the participants - teachers and students - surveyed. There is then a substantial section which presents the responses of the teachers at an aggregate level, i.e. spanning the four countries. Section 4 provides the complementary aggregate data from the surveys of students. In the final section, there are comments made on the ways in which the data from each country fits (or not) with the overall picture. This section will provide strong evidence of diversity at all levels with views influenced strongly by local environment.

It should be noted that the surveys were confined to teaching staff and students. Heads of Department were included but not Head-teachers. Other stakeholders were interviewed, as described in the Methods Chapter, but their views are only reported in the later Qualitative Data Chapter.

#### **5.2 Participants**

The participants were drawn from the 18 schools that were visited. The schools themselves are described in Chapter 4. In this section further details are provided of the participants in the two surveys.

A total of 44 teachers were surveyed. Table 5.1 shows their distribution by country and type of school. As might be expected, the large majority were teaching in co-educational schools. The geographical distribution is uneven as the opportunities to recruit teachers varied from country to country.

**Table 5.1:** The distribution of the 44 teachers surveyed by country and type of school. In the total column, the number of male teachers is shown in brackets.

	Country				
Type of School	Ghana	South Africa	Nigeria	Tanzania	Total
Boy's Only	2	0	1	0	3
Girls Only	0	0	1	5	6
Co-educational	5	12	3	15	35
Total	7 (6)	12 (10)	5 (4)	20 (16)	44 (36)

There was a broad span of age of teachers (Table 5.2). The large majority of those surveyed were established teachers with considerable experience. It is reasonable to assume that their views include the existing consensus though there is likely to be some weighting towards those more interested in innovation.

**Table 5.2:** The ages of the teachers surveyed.

Age of teacher	Number in Band
30 years and below	9
30-39 years	18
40-49 years	10
50-59 years	7
60 and above	0

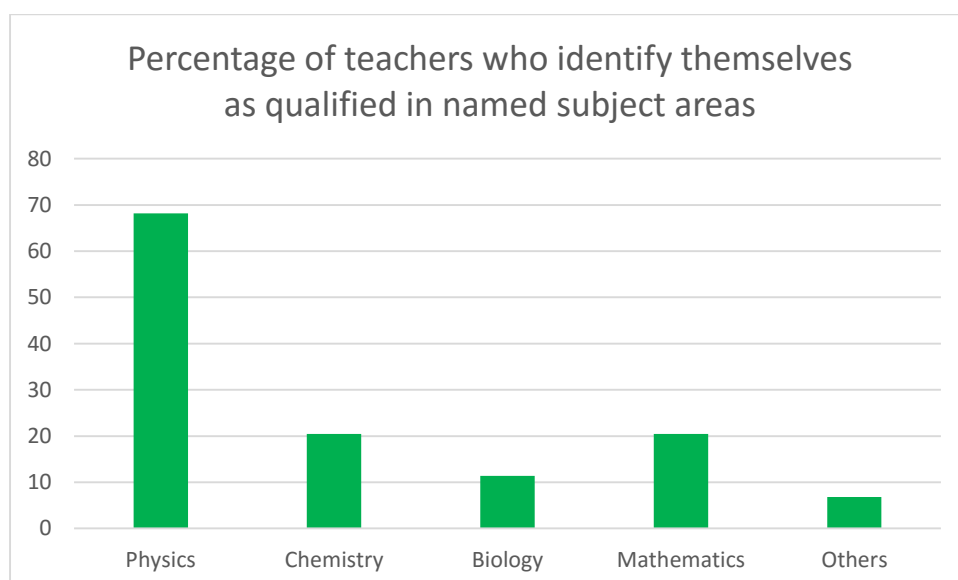
The teachers were asked about their tertiary educational and professional qualifications (Table 5.3). Almost half did not have degrees, even though they were teaching physics at advanced secondary level. A minority had science/physics degrees and a smaller minority had postgraduate qualifications, with just four of these in science subjects.



**Table 5.3:** The declared qualifications of the teachers surveyed.

Qualification	Number of teachers
Pre-degree Certificate in Education	20
First degree in Education	11
First degree in Other Subject	13
PG.Dip.Ed.	5
M.Ed.	1
M.Sc.	4
Ph.D.	0

Figure 5.1 shows the subject specialisms of the teachers. The large majority consider themselves to be qualified to teach physics but that still leaves nearly one-third who do not consider themselves qualified to teach a subject that they are teaching. Many of the teachers took the view that they were qualified to teach a number of science subjects.



**Figure 5.1:** The declared areas of qualification of the teachers surveyed.

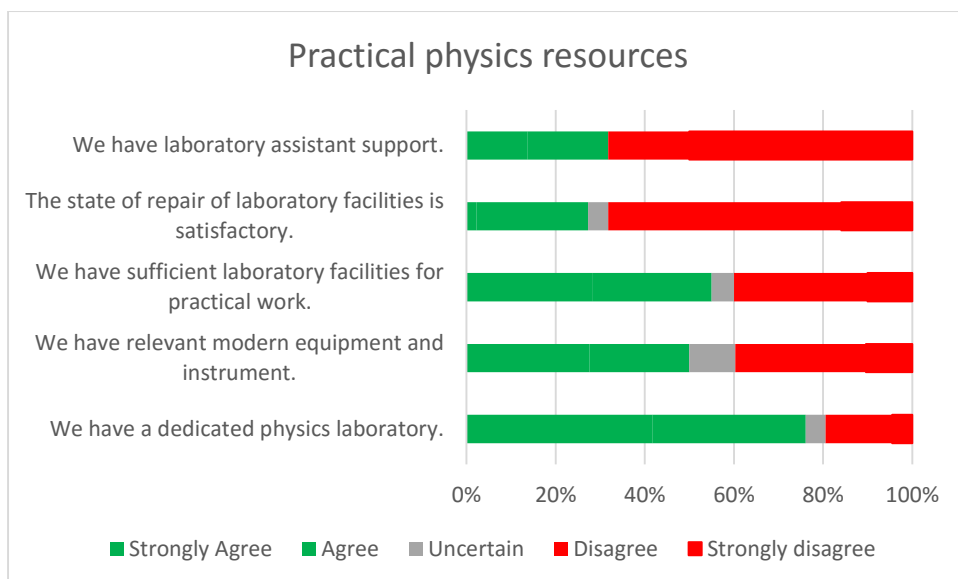
Students were not asked for personal information. The surveys were completed in scheduled class times for students at senior secondary level, i.e. the students were 16-18 years old. The response rate from the 550 students was 100%. There were 226 boys and 324 girls participants. Table 5.4 provides data on the type of school attended by the students and their location. It can be seen that the large majority of participants came from co-educational schools. Views were obtained from rural, urban and suburban schools.

**Table 5.4:** The type of school and school location for the students who completed the survey.

School location	Urban		Suburban		Rural		Total
Gender	Male	Female	Male	Female	Male	Female	
School Type							
Co-educational	43	62	85	100	49	53	392
Boys only	31	0	18	0	0	0	49
Girls only	0	109	0	0	0	0	109
Totals	74	171	103	100	49	53	550

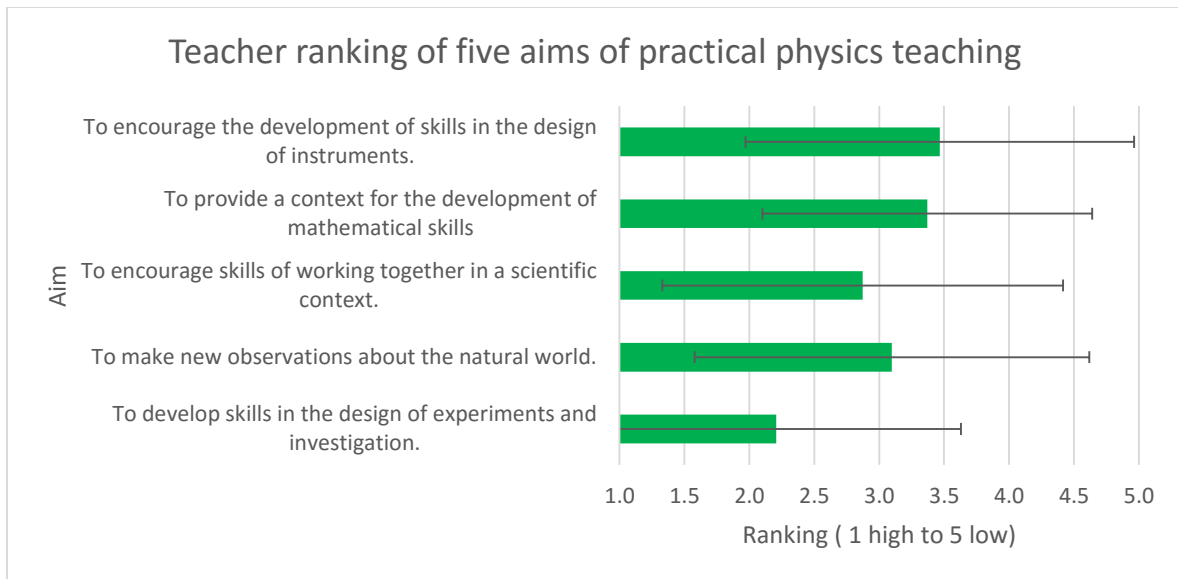
### 5.3 Teacher Survey Data

Teachers were asked to respond to a series of statements about the resources available in their schools. The overall view is that resources are not adequate. Although the majority assert that they have a dedicated physics laboratory, there are major concerns about the adequacy and state of repair of the laboratory facilities. A clear majority of the teachers state that they do not have laboratory assistant support.



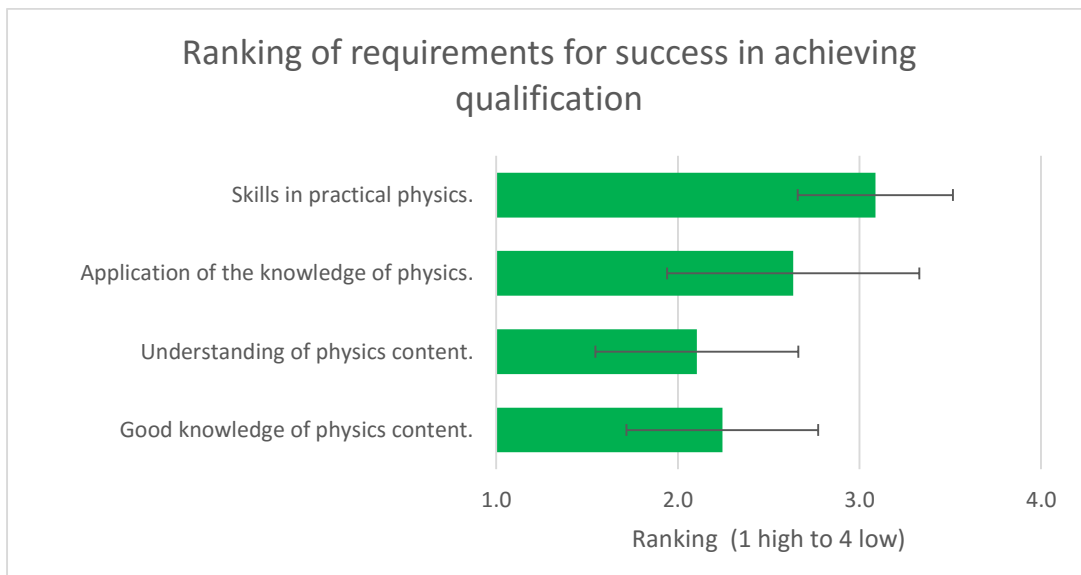
**Figure 5.2:** Teacher views on school resources.

In Chapter 2, there was a discussion of the aims of practical physics teaching. Many lists of aims have been suggested (Kerr, 1963; Betty and Woolnough, 1982). For this thesis, five aims were proposed. Teachers were invited to rank the five aims in order of importance. The results are in Figure 5.3. The mean ranking varies from 2.2 to 3.5. The error bars in the figure are the standard deviations. These should be treated with caution as the data are not normally distributed but they indicate diversity of view within a broad consensus that the development of skills in the design of experiments is the most important aim. However, the physics teachers rated the five aims of practical work in order of importance as follows: (i) to develop skills in the design of experiments and investigations (mean 2.2); (ii) to encourage skills of working together in a scientific context (mean 2.9); (iii) to make new observation about the natural world (mean 3.1); (iv) to provide a context for the development of mathematical skills (mean 3.4); and (v) to encourage the development of skills in the design of instruments (mean 3.5).



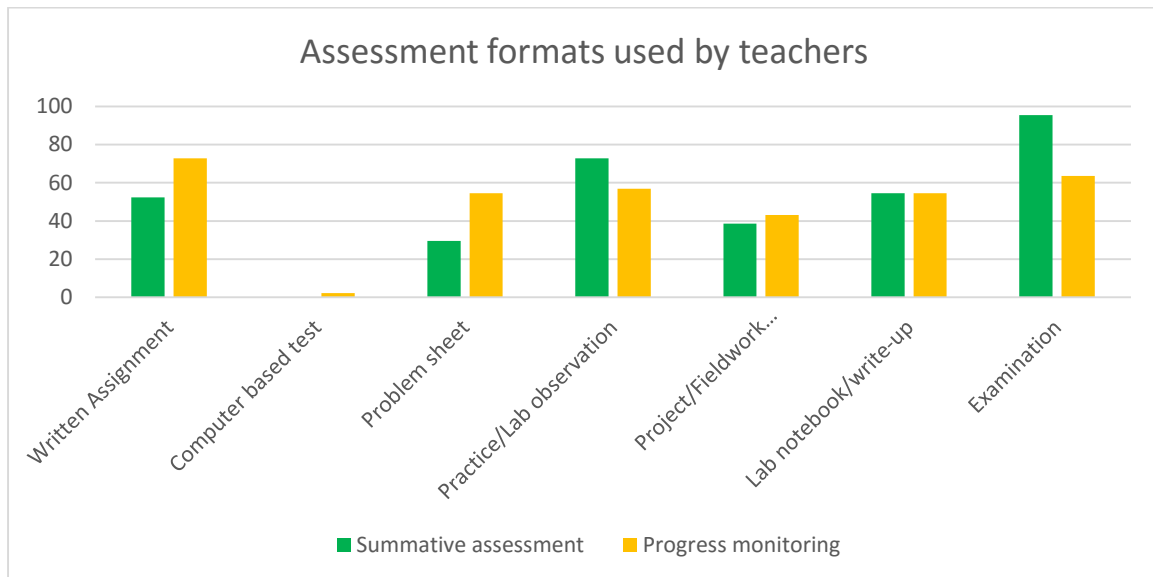
**Figure 5.3:** Teacher views on the aims of practical physics teaching.

Data in Figure 5.4 reveals the ranking of the qualification requirements. The highest ranking by the physics teachers was *understanding of physics content* with mean (2.1) followed by *good knowledge of physics content* with mean (2.2). The third ranked requirement was the *application of the knowledge of physics* with mean (2.6) while *skills in practical physics* with mean (3.1) was the least ranked requirement for qualification by the physics teachers.



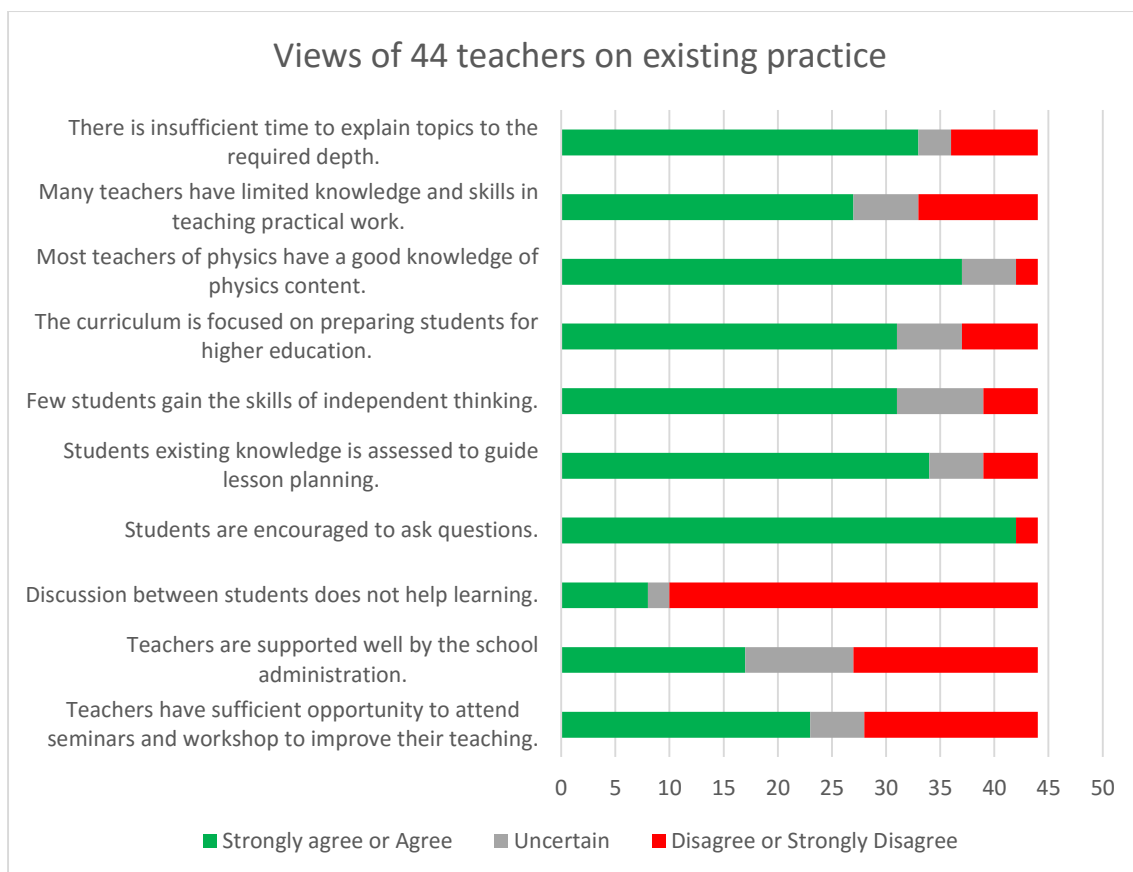
**Figure 5.4:** Teacher ranking of the requirements for student success in gaining qualification.

Teachers were asked to indicate the assessment methods used for the award of qualifications and also for monitoring students' progress. The responses showed that there is a dominance of traditional forms of assessment: examination is seen as the main method both summatively and formatively (Figures 5.4 and 5.5). There is an absolute absence of e-learning methods



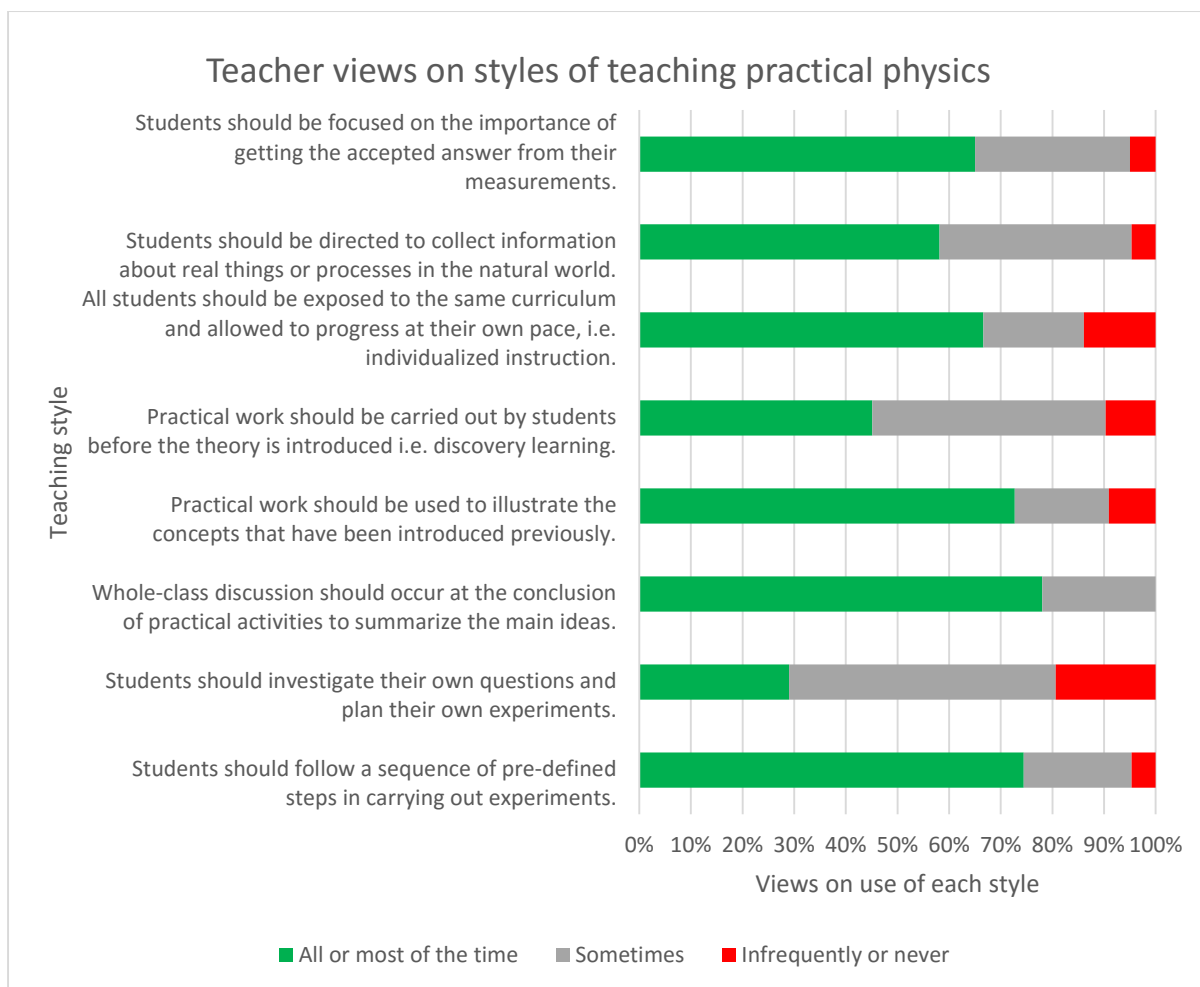
**Figure 5.5:** Teacher views on the forms of assessment that are used summatively and formatively.

Teachers were asked whether they agreed with statements that described aspects of practice that the pilot study had suggested might be relevant. Following usual practice, the response was provided through a 5 point scale spanning from 'Strongly Agree' to 'Strongly Disagree'. The questionnaire used both positively and negatively framed statements, i.e. where common perceptions of good practice might be expected to provoke agreement or disagreement. Figure 5.6 shows the responses. The agreement with the first two statements may be regarded as matters for concern.



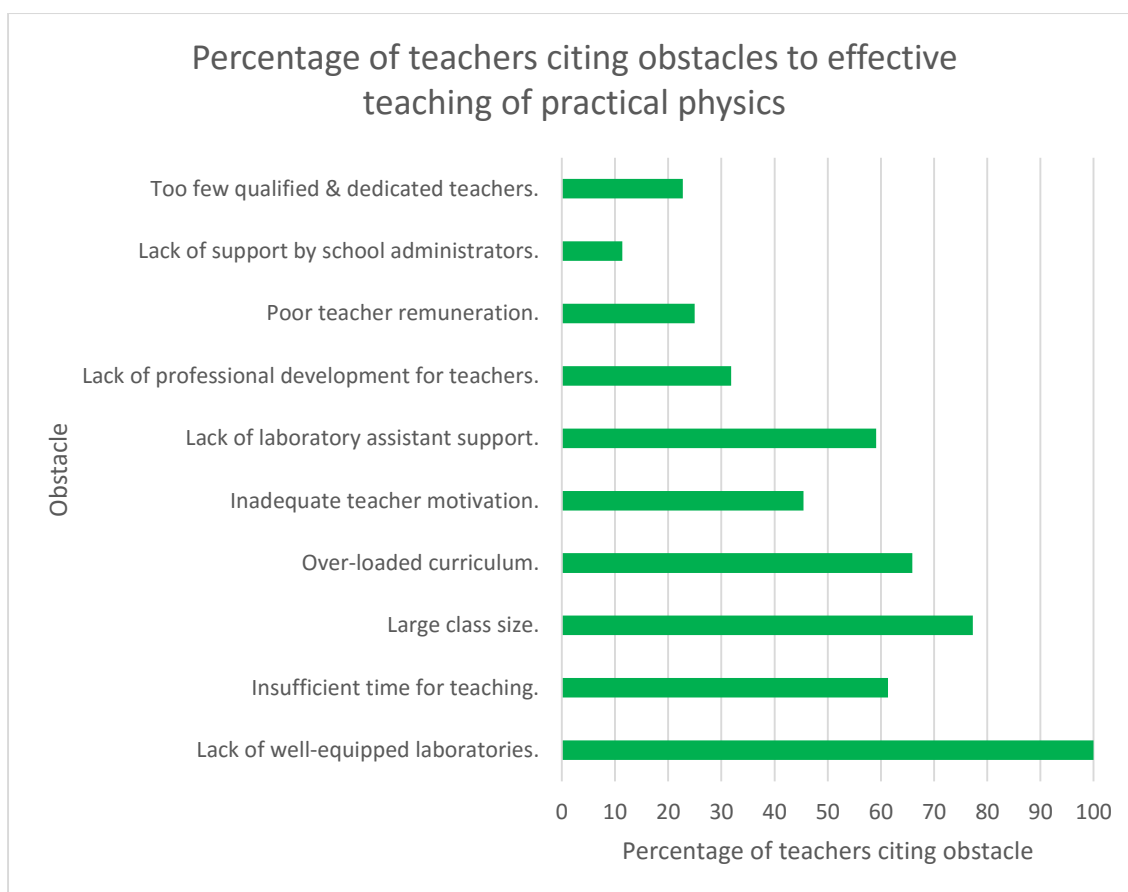
**Figure 5.6:** The views of the 44 teachers on various statements about present teaching practice.

Teachers were asked to put a tick against five approaches (from a list of eight) that they thought were important and to indicate how often they believe this approach should be adopted. Many of the teachers believed that students should follow a sequence of pre-defined steps in carrying out experiment as students should be focused on the importance of getting the accepted answer from their measurement. The assumption, from the views of the teachers on the teaching approaches, is that practical work is carefully controlled and leads to accepted answers.



**Figure 5.7:** The views of teachers on the extent to which particular teaching styles should be used in their classes.

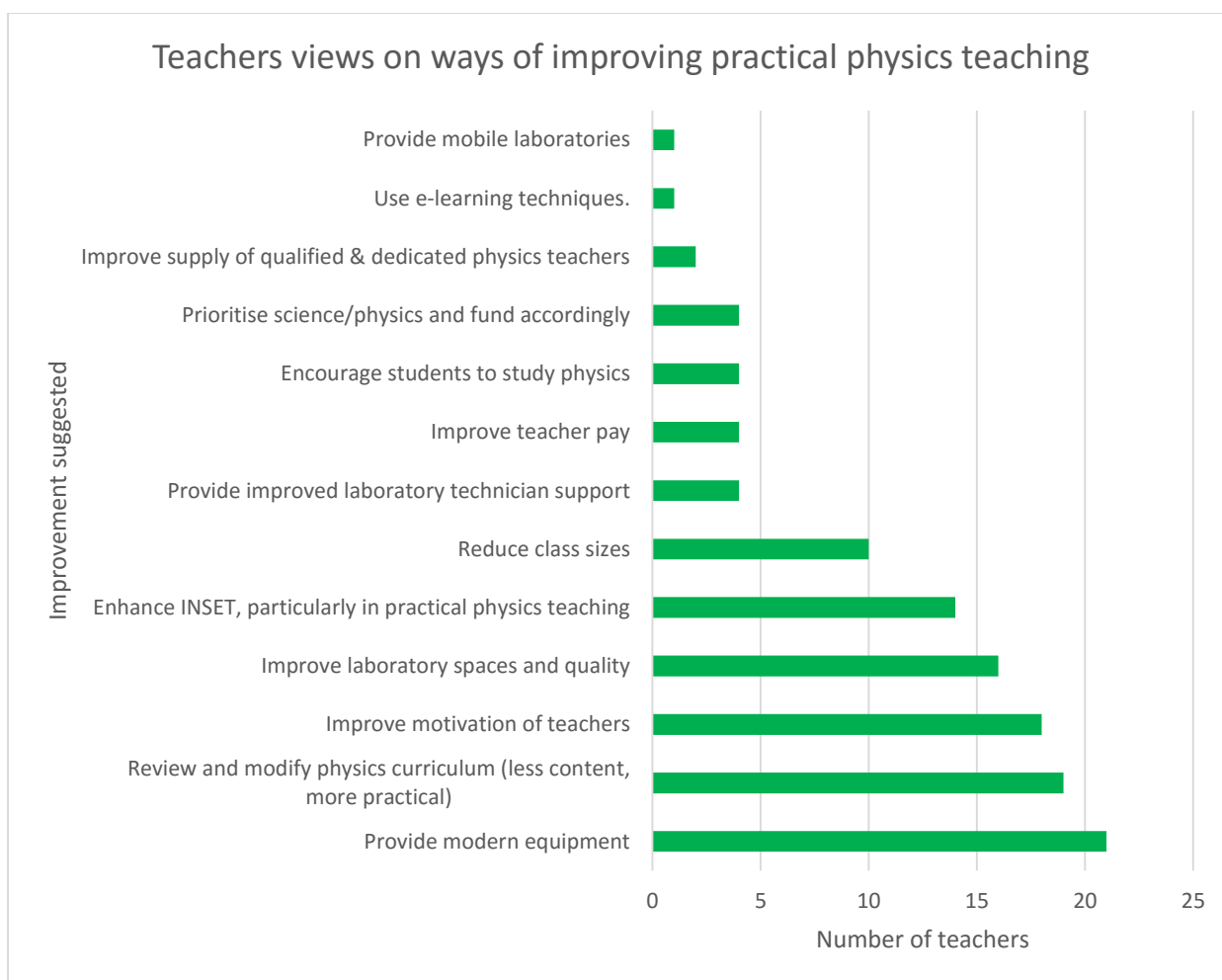
The teachers who were surveyed were asked to identify the five most significant obstacles that they faced in teaching practical physics. They were provided with a list of 10 possible choices but invited to add other factors if appropriate. None of the 44 teachers added a new item. Figure 5.8 shows the percentage of teachers who chose each of the 10 possible obstacles. Time and material resource issues dominate. However, it is also apparent that there are issues of motivation, possibly linked to pay and the level of demands on the teachers.



**Figure 5.8:** The views of teachers on the obstacles to effective teaching of practical physics.

Teachers were asked to suggest ways in which practical physics teaching might be improved. A total of 118 responses from 44 teachers were suggested in a free format entry. Similar suggestions have been gathered together under a single row with an inclusive wording. Suggestions range from local to national actions. The suggestions from the teachers reflect their own experiences as the large majority of the teachers want; the provision of modern equipment, modification of the physics curriculum in terms of content reduction, and more time for practical. Most of the teachers also suggested improved motivation and regular in-service training, particularly in practical physics teaching. However, there is little said about e-learning or discovery learning.





**Figure 5.9:** Teacher views on the ways in which practical physics teaching might be improved.

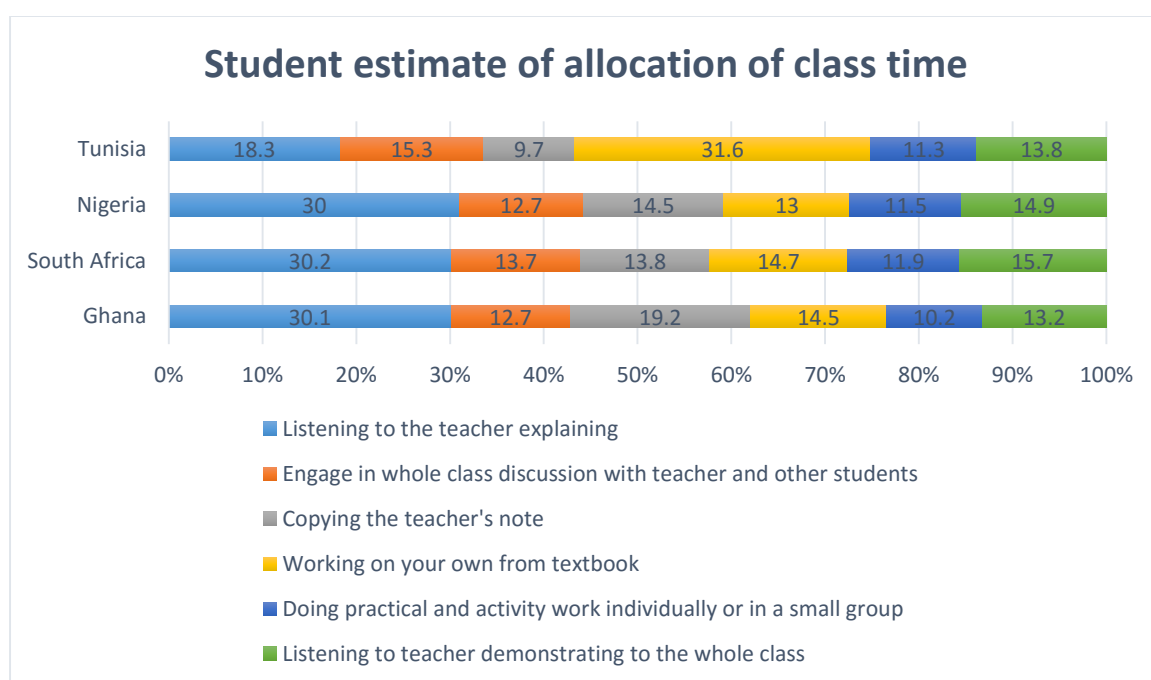
## 5.4 Student Survey Data

As already noted, a total of 550 students participated in the student survey. The student questionnaire was fairly short and was based on students' personal experiences. It contained a number of free format responses.

Students were asked to estimate the percentage of the time spent on six types of classroom activity. Figure 5.10 shows their overall responses in percentage. The figures reveal that a large majority (75%) of the total time devoted to the teaching and learning of physics lessons is allotted to working from textbooks, teacher explanations, demonstrations and note copying by the students. About 14% of the time is used in engaging in whole class discussion with the teacher and other students while only a little (11%) of the lesson is devoted to students taking part in group practical activities. It can

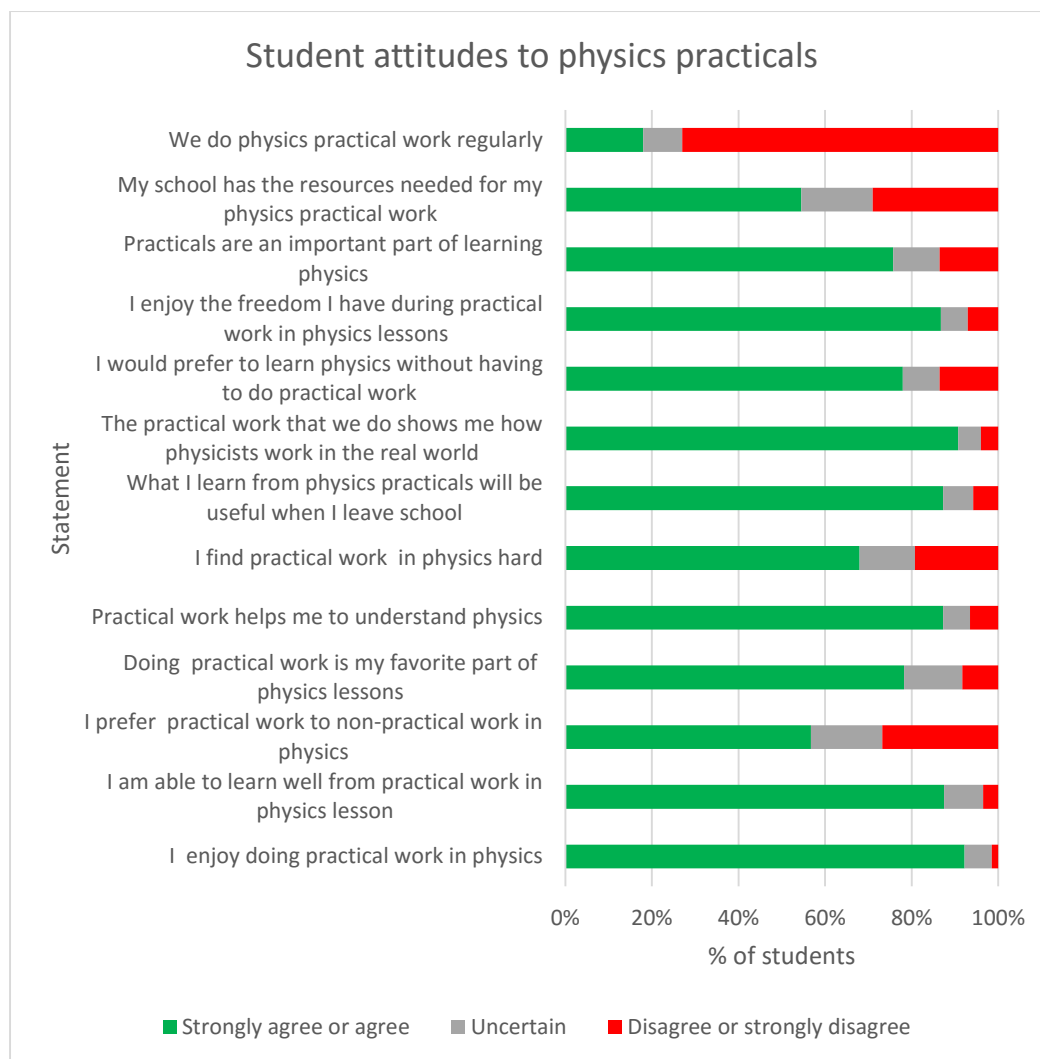
be seen that the learning experience tends to be passive and there are less frequent independent student lessons.

The estimates of the students are broadly similar across the four countries with the time spent on practical activities varying from 10.2% to 11.5%. However, the students in Tunisia asserted that the largest percentage of their teaching time is devoted to “working on their own from textbook”. This time is switched from teacher-centred explanation and is probably explained by the Tanzanian initiative to provide every student with a textbook.



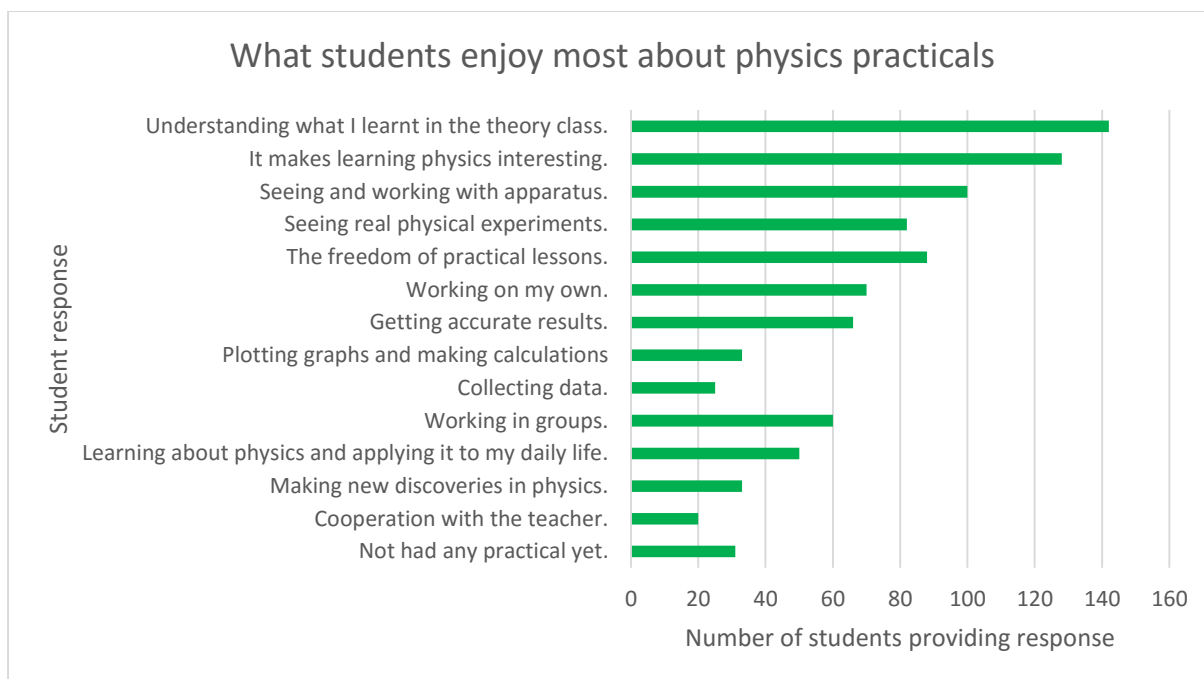
**Figure 5.10:** Students estimates of the ways in which class time is allocated.

Students were asked about their attitude to practical work in physics by indicating their level of agreement with thirteen statements. The responses are presented in Figure 5.11. The positive statements relating to the affective domain, such as enjoyment, preference and freedom were strongly agreed or agreed by the large majority of the students across the four countries surveyed. They reported that they enjoyed doing practical work, it is their favourite part of physics lessons and they prefer it over non-practical lessons. They also preferred the freedom they had during practical work compared to the theory. On the cognitive aspect, students claim they were able to learn and understand by actually doing the practical work. A large majority of the students agreed with statements relating to the value of practical work beyond school physics



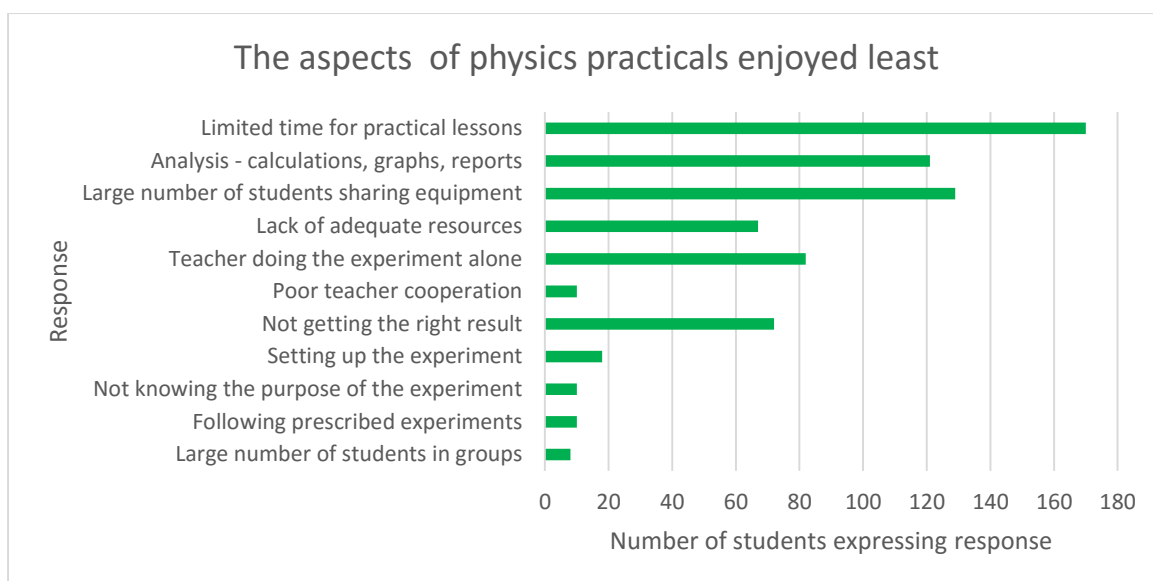
**Figure 5.11:** Student attitudes to physics practical.

Students were asked to write down what they enjoy most about physics practical. The 550 students provided 928 items which were gathered together under phrases of very similar meaning. The precise wording of each item in Figure 5.12 is drawn from student responses. There were differences in the ways that students approached this task. The students from South Africa and Tanzania provided one response each. Those from Ghana and Nigeria provided typically 1-3 responses. All responses reflect student views and are therefore included. The data suggest that students enjoy working with apparatus while recognising that practical work can help in the understanding of theory.



**Figure 5.12:** The aspects of practical work in physics that students enjoy most.

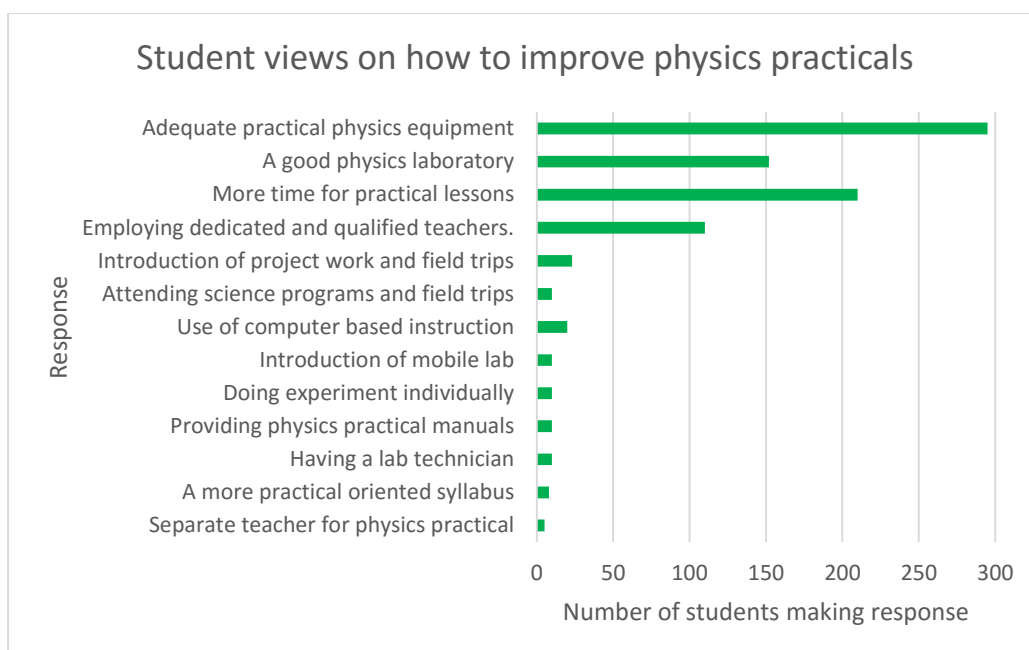
Students were asked to write down what they least enjoy about physics practical. The 550 students provided 697 items which were gathered together under phrases of very similar meaning. The wording of each item in Figure 5.13 is drawn from student responses. Once again, there were differences in the ways that students approached this task. The students from South Africa and Tanzania provided one response each just as they did in Figure 5.12, probably because of their limited exposure to practical activities. Those from Ghana and Nigeria provided typically 1-2 responses. All responses reflect student views and are therefore included. The data suggest that students were not satisfied by the limited time for practical activities in their physics lessons and by the sharing of equipment in large groups. It may also be noted that many of the students did not enjoy tackling the analytical tasks required. It may be hypothesised that they lack the relevant skills required and therefore are anxious about such activities.



**Figure 5.13:** The aspects of practical work in physics that students enjoy least.

Students were asked to suggest ways in which the teaching and learning of practical physics might be improved in their schools (Figure 5.14). A total of 873 responses were suggested in a free format entry. Similar suggestions have been gathered together under a single row. The suggestions from the students reflect their own views on an ideal practical physics sessions. The majority of the students want modern practical physics equipment, access to a good physics laboratory, more time for practical lessons and dedicated and committed physics teachers. A few students in South Africa suggested the ‘e-learning approach’ to practical physics teaching while this was not mentioned by their counterpart in Nigeria, Ghana and Tanzania.

Unfortunately, it was not possible to pursue a meaningful exploration of gender differences in the survey responses. Although the total number of respondents was large, i.e. 550, the proportion of the two sexes was very different for different locations and thus a major confounding factor was present. In addition there was inadequate statistical power to isolate gender effects given the variability in response. Similar arguments undermined efforts to look at gender effects in the teacher survey data.



**Figure 5.14:** Student views on the how physics practical could be improved.

## 5.5 Individual Country Comments

This section will look briefly at the data that is specifically related to each of the countries visited in this study. It will seek to identify areas of consensus and to highlight diversity in the teaching and learning of practical physics in schools.

### 5.5.1 Ghanaian Opinions

In 2015, Ghana had 526 public senior high schools. The survey participants were drawn from three schools from three different education districts - one each from urban, suburban and rural areas. The research visit took place between 7th July and 14th July 2014. The schools were as shown in Table 5.5

**Table 5.5:** The schools in Ghana from which the survey participants were drawn

Locations	Enrolment	Studying physics as a separate subject
Suburban (school A)	1300	23%
Urban (school B)	1000	30%
Rural (school C)	2000	15%

Seven (6 male and 1 female) physics teachers were surveyed and completed the questionnaires. It is interesting to note that all the seven (7) physics teachers surveyed had a degree. However, none of them had been able to go further and achieve higher degrees in science or education

The majority of the teachers say that they have a dedicated physics laboratory but there is a shortfall of laboratory assistant support. There is a general consensus on the aims of practical physics. The Ghanaian physics teachers rated the '*development of skills in the design of experiments*' as being of most importance. This view was shared by their Nigerian counterparts, possibly because practical physics is an examined part of the West Africa Senior School Certificate Examination (WASSCE).

The Ghanaian physics teachers approach to the teaching of practical physics is quite closed. They believe that students should be focused on the importance of getting the accepted answer and also follow a sequence of pre-defined steps in carrying out experiments. This teaching approach has a long tradition – there is little interest in inquiry/discovery learning.

Commenting on the most important obstacles to progress in practical physics teaching, the teachers mentioned "lack of well-equipped laboratories and large class size". This view was supported by the observation of about 50 science students in a single class during the research visit. The teachers suggested improvement could be achieved by allowing enough time for practical activities and providing regular INSET for physics teachers.

100 physics students completed the student questionnaire. They were Senior High School year 2 physics students of age 17 yrs. Table 5.6 gives a breakdown of the students.

**Table 5.6:** A breakdown of the students surveyed in Ghana

<b>Gender</b>	Boys (71%)	Girls (29%)	
<b>Type of School</b>	Coeducational (69%)	Boys only (31%)	
<b>Location of school</b>	Urban (37%)	Suburban (47%)	Rural (22%)

Despite the emphasis placed on practical physics in the school curriculum, the students surveyed in this study indicated that the bulk of their time is spent on '*listening to the teachers explaining, and copying the teacher's note*'. Anecdotally, there was evidence that suggests there is little emphasis on practical work. The researcher saw a lot of unused physics equipment in the physics laboratory during the visit.

The students shared consistent views in response to the statements relating to their attitude to practical work but suggested that their schools should be well-equipped with physics apparatus and there should be more time for practical lessons in the school timetable.

### 5.5.2 South African Opinions

South Africa has nearly 700 Further Education and Training (FET) schools with a total enrolment of about 775,000 students across the nine provinces (Department of Basic Education, 2015). The present study was carried out in six schools within two provinces (Gauteng and Western Cape). The research visit took place between January 19th and January 29th 2015. Their characteristics are described in Table 5.7

**Table 5.7:** The schools in South Africa from which the survey participants were drawn.

Location	Enrolment	Studying physical science as a separate subject
Suburban (school D)	531	11%
Rural (school E)	700	19%
Urban (school F)	1000	7.5%
Suburban (school G)	1000	100%
Urban (school H)	560	100%
Rural (school I)	1200	28%

The average number of students per class in the schools visited stood at 46. Most of the schools visited had at least one physical science teacher. Twelve physical science teachers (10 male and 2 female) were surveyed during the visit. Their average teaching experience was 14 years.

Nine of the physical science teachers surveyed had at least a Bachelor degree whilst three had a lower certificate. This may be contrasted with the fully graduate sample surveyed in Ghana and Nigeria. A further difference is that three of the graduates also had Masters Degrees in a science subject. Only five teachers of the twelve had a physics qualification as shown in Table 5.8.



**Table 5.8:** Declared subject area of South African teachers surveyed

Subject	Number
Physics	5
Chemistry	4
Biology	2
Mathematics	1
Others	0
<b>Total</b>	<b>12</b>

As in Ghana, the large majority of the teachers said there was a dedicated physics laboratory in their school but with no laboratory assistant to support them. According to the teachers, practical work forms an important part of assessing student progress but has little relevance summatively as the exams are theory based. It is reasonable to assume that most of the teachers don't attach much importance to practical activities in their teaching of physics and, in turn, this may be reflected in the poor state of repair of the laboratories seen.

The South African teachers rated *"making new observations about the natural world"* as the most important aim of practical work in physics as against the *"development of skills in the design of experiments"* rated as the most important aim according to teachers in the other three countries. One of the most favoured approaches to practical physics teaching as stated by South African teachers is that *'students should follow a sequence of predefined steps in carrying out experiments'*. It appears that students are not allowed to investigate their own questions and plan their own experiments. Similar views were expressed by Ghanaian and Nigerian physics teachers.

The physical science teachers were clear on the obstacles to progress in their teaching of practical physics. Most of them believed that *"lack of well-equipped laboratory and laboratory assistant support"* are the main barriers to progress while they suggested *"equipping physics laboratories and provision of laboratory technician"* will help significantly.

A total of 200 students (84 boys and 116 girls) were surveyed. They were drawn from Grade 12 students and were usually 18 years old.

**Table 5.9:** A breakdown of the students surveyed in South Africa.

<b>Gender</b>	Boys (42%)	Girls (58%)	
<b>Type of School</b>	Coeducational (100%)	Boy only (0)	
<b>Location of school</b>	Urban (33%)	Suburban (55%)	Rural (12%)

They expressed the clear view that the bulk of the time in their physics lessons was devoted to teacher explanations and demonstrations to the whole class. Group practical work is carried out rarely. However, the students were very positive in their attitude to practicals as they claimed to have enjoyed such work and most believe that they learn well from the few practical activities they have carried out. It appears that the analysis aspects of practical physics are enjoyed least and students would like more modern practical physics equipment and more time for practical lessons. Such views are common in the other countries.

### 5.5.3 Nigerian Opinions

In 2010 there were approximately 4 million students enrolled for senior secondary school. Recent statistics are not available for the number of schools. For this research, the participants were drawn from five schools. The schools sampled allow the Researcher to hear from both the North and the South of the country. As indicated earlier, purposive sampling was employed to draw on a spectrum of opinions. The schools were as shown in Table 5.10.

**Table 5.10:** The schools in Nigeria from which the survey participants were drawn.

<b>Location</b>	<b>Enrolment</b>	<b>Studying physics as a separate subject</b>
<b>Suburban (school J)</b>	635	18%
<b>Rural (school k)</b>	403	20%
<b>Urban (school L)</b>	450	16%
<b>Urban (school M)</b>	250	20%
<b>Rural (School N)</b>	350	17%

Five schools from different education districts were used in the study, one from urban, two from sub-urban and two from rural areas. In these schools, the average number of students per physics class stood at 26. There were five (4 male and 1 female) physics teachers surveyed during the visit that took place between March 20<sup>th</sup> and March 25<sup>th</sup> 2015. There was one physics teacher for each school with an average teaching experience of 12 years. All five teachers were holders of first

degrees in physics education and four also had a higher qualification (Postgraduate Diploma in Education (2), Masters in Education (1) and MSc (1)).

**Table 5.11:** A breakdown of the students surveyed in Nigeria

<b>Gender</b>	Boys (45%)	Girls (55%)	
<b>Type of School</b>	Coeducational (57%)	Boys only (18%)	Girls only (25%)
<b>Location of school</b>	Urban (25%)	Suburban (45%)	Rural (30%)

There were about one hundred students who completed the survey. Table 5.11 provides basic background information on these students. They were final year senior high school students with a median age of 17 years. The response rates to the questionnaire were about 25% of the students from urban schools, 45% from suburban schools and 30% from rural schools.

According to the teachers, most of the schools in Nigeria as a whole do not have a dedicated physics laboratory. This assertion is consistent with the anecdotal evidence from the research visit, where most schools had a single laboratory shared between the three science subjects (Physics, Chemistry and Biology). The teachers' responses in the survey indicated that they have laboratory assistant support but are not satisfied with the state of repair of laboratory facilities.

The Nigerian teachers indicate that practical activities form an important part of formal qualifications: students have to take a separate practical physics paper in the West Africa Senior School Certificate Examination (WASSCE). They were also unanimous on the most important aims of practical work in physics. Nigeria teachers viewed *“development of skills in the design of experiments”* as the most important aim of practical work in physics, a view they share with their Ghanaian counterparts. The teachers believed that the best approach is for students to *‘follow a sequence of predefined steps in carrying out experiments’*, a view shared by their colleagues in Tanzania, South Africa and Ghana. This shows a neglect of inquiry and discovery learning approaches.

The major obstacles to progress in practical physics teaching according to the teachers, are *‘lack of a well-equipped laboratory’* and *‘insufficient time for teaching’* while they suggest that progress would be made with a state of the art laboratory for practical activities and regular INSET for physics teachers.

Despite the fact that practical work plays an important role in formal qualification, Nigerian students stated that most of their learning time is devoted to *‘listening to the teacher explanation and engaging in whole class discussion with teachers and other students’*. This shows that teacher

centered or teacher directed activities dominate physics lessons and there is less frequent independent practical work by students.

Nigerian students also have a positive attitude towards practical physics lessons (Figure 5.11), they believe it enables them to understand what is being taught in the theory class. However, some of the students find it difficult to analyse practical activities, most especially in the areas of calculations and plotting graphs of experimental results. They echo their teachers by suggesting that their school should be provided with adequate physics equipment and a state of the art physics laboratory.

#### 5.5.4 Tanzanian Opinion

The study was carried out in four schools in two different locations (rural and urban) between 11<sup>th</sup> July and 18<sup>th</sup> July 2015. All of the schools visited had at least one physics teacher mostly with limited physics qualifications. The schools are described in Table 5.12.

**Table 5.12:** The schools in Tanzania from which survey participants were drawn.

Location	Enrolment	Studying physics as separate subject
Rural(school O)	281	28%
urban(school P)	700	5%
urban(school Q)	567	53%
urban(school R)	546	19%

Although only four schools were visited, it was possible to survey additional teachers who were attending a training event. In total there were twenty physics teachers (16 males and 4 females) surveyed in the study. Their qualifications were considerably lower than in the other three countries. Only three were graduates (two had a B.Ed. and one had a B.Sc.). All the others had a Diploma in Education. The recent priority in Tanzania has been primary education and training of specialist science teachers has been a lower priority.

There are 44% of students from coeducational and 56% from single sex girl's schools. About 150 physics students completed the questionnaire. They were drawn from Forms V and VI students with a typical age of 18 years. Table 5.13 gives some basic information on the background of the students.

**Table 5.13:** A breakdown of the students surveyed in Tanzania.

<b>Gender</b>	Boys (17%)	Girls (83%)	
<b>Type of School</b>	Coeducational (44%)	Boys only (0%)	Girls only (56%)
<b>Location of school</b>	Urban (83%)	Suburban (0%)	Rural (17%)

All the schools visited had a dedicated physics laboratory according to the teachers. This may reflect the Presidential policy on school laboratories described in Chapter 3. However the teachers claimed to be lacking laboratory assistant support, a problem shared by their Ghanaian counterpart. Practical work in Tanzania forms a significant part of the formal qualification just as it is in Ghana and Nigeria as students write a practical physics examination (either real or ‘alternate to practical’) for the Certificate of Secondary Education Examination (CSEE) at O level and in Advance Certificate of Education Examination (ACEE) at A level.

On the most important aims of teaching practical physics, Tanzanian physics teachers shared a similar view to their counterparts in Ghana and Nigeria as they see the most important aim to be the ‘*development of skills in the design of experiments and investigation*’. There is a general consensus on the best teaching approaches to practical physics among the teachers in the four countries as Tanzanian teachers also believed that ‘*students should follow a sequence of pre-defined steps in carrying out experiment and students should be focused on the importance of getting the accepted answer from their measurement*’.

Lack of well-equipped laboratories and large class size were seen as the most important barriers to effective teaching and learning of practical physics as they suggested that ‘*motivation in terms of increased allowance*’ and ‘*equipping physics laboratory with modern equipment*’ would go a long way in helping them to improve on the teaching of practical physics.

The Tanzanian students said that the majority of the total time devoted to teaching and learning in physics lessons is allotted to ‘*working from student’s own textbook, teacher explanations, demonstrations and note copying by the students*’ with little time spent on practical activities. However, the Tanzanian students reported that they worked on their own with a text book for nearly one third of the time. This may reflect teacher shortages and a policy of free distribution of text books. All the students were very positive in their attitude to practical physics just as their counterparts were in other countries, but were not satisfied with the lack of resources and limited time for practical activities. They later suggested that ‘*providing adequate practical physics equipment*’ and ‘*more time for practical activities will improve their learning of practical physics*’. It

was interesting that the Tanzanian students departed from the consensus in disagreeing with the statement '*I find practical physics hard*'.

## 5.6 Summary of Findings

This section summarizes the above comments and extends them to views which are not country specific. Student responses are discussed first.

The students estimate that the majority of the time allocated to physics lessons is devoted to teacher explanation, demonstration and discussions with other students while little time is devoted to group based practical work. Teacher centered activity predominates.

Positive statements relating to the affective domain were supported by most of the students. On the cognitive aspect, students claim they were able to learn and understand by actually doing the practical work. Interestingly, most of the students were able to agree to statements relating to the value of practical work beyond school physics.

Most of the students suggested that their school should be provided with adequate practical physics equipment and also a separate physics laboratory. They also suggested that teachers should devote more time to physics practical lessons and that the curriculum should be practically oriented and be taught by competent and committed teachers. Some also suggested that there is need for a lab technician to monitor and guide them during the practical activity.

Teachers gave a ranking of requirements for success in achieving qualification in physics. Interestingly, skills in practical physics was given the lowest ranking while the understanding of physics content was highly ranked by the physics teachers. A majority of the teachers believed that the main aim of practical work in physics is to develop skills in the design of experiments and investigation while the development of skills in the design of instruments was the lowest rated aim by the teachers

Physics teachers believed that lack of well-equipped laboratories, large class sizes, overloaded curriculum, insufficient time for teaching and lack of laboratory assistant support were the greatest obstacles to the teaching and learning of practical physics. To improve the study of practical physics, most respondents suggested that the teachers need to be well motivated and provided with modern physics equipment and laboratory facilities. Also, there should be a review of the overloaded curriculum, reduction in the ratio of students to teachers, and sufficient time. There was widespread agreement that having dedicated and qualified physics teachers with frequent in-service training would improve the study of practical physics

## **CHAPTER 6**

### **QUALITATIVE RESULTS**

This chapter presents the findings gathered from the interviews and focus group discussions across the countries visited in the study. Key stakeholders in physics education participated in the interviews. They included; physics teachers, school heads, curriculum officers, heads of science departments, officials from Ministries of Education, physics educators from the universities and colleges of education, and Institute of Physics (IoP) volunteer coordinators. In addition, focus group meetings were held with the students in the schools visited by the Researcher. The interviews and focus group discussions were conducted between 14<sup>th</sup> of July 2014 and 19<sup>th</sup> of July 2015.

The results are presented in relation to the research questions that were formulated to guide this study. For each question a numerical indication is given of the prevalence of the themes or areas raised by the respondents across the four countries. These quantitative data should be treated with caution as the participants are not representative samples of their stakeholder groups and the classification themselves are somewhat subjective, not least because a given remark may cross the boundaries between themes and research questions. However the numerical data does provide a broad indication of the concerns of the interviewees. In addition, typical or noteworthy quotes are provided for each theme. As already described, the quotes have been edited to ensure anonymity and to mitigate ambiguities that arise from trivial grammatical slips. It must be noted that several of the quoted comments are relevant to more than one theme and in some cases quotes have been deliberately repeated under each of the themes they address.

#### **6.1 Stakeholder Responses**

##### **6.1.1 What are the current aims of the practical physics curriculum in African schools?**

In Chapter 2, five possible aims for practical work were identified. These could have been used as the basis for categorization of stakeholder responses. However, as already indicated, a more ethnographic approach would be more likely to uncover concerns and opinions that diverged from previous literature and practice. Accordingly, broad themes were chosen that brought together the main strands of stakeholder discussion. These were further categorized in terms of opinions. The main themes were: (i) broader physics learning with opinions on understanding and reinforcing the theory; (ii) practical specific learning which involves skills acquisition and investigation of physics concepts, (iii) the exploration opportunities of practical physics, (iv) motivation which involves

sustaining the interest of the students in physics but may also include linking theory to the real world or relating physics to life activities, and, finally, (v) the linking of practical physics to economic needs and priorities.

**Table 6.1** Overall themes and number of respondents on aims of practical physics. Participants made 118 separable comments on the aims of practical physics in African schools.

Country (Number of interviewees)	Ghana (15)	S. Africa (21)	Nigeria (12)	Tanzania (18)	Total (66)
Theme					
(i) Broader physics learning	14	13	7	9	43
(ii) Practical specific learning	10	9	7	8	34
(iii) Exploration and discovery	4	6	4	1	15
(iv) Motivation	4	7	5	5	21
(v) Economic needs and priorities	1	-	2	2	5

**(i) Broader Physics Learning.** The largest number of comments related to the perceived impact that practical physics had on broader physics learning, i.e. it complemented or enhanced other parts of the curriculum. Participants commented that practical work improved factual knowledge and that it gave students deeper understanding of the subject. Some of the participants also believed that practical physics helps in reinforcing the theory that is being taught in class. One of the physics teachers said:

*‘The aim of the practical physics curriculum is to improve the knowledge of the student concerning the said topic in physics. Some topics may be difficult to understand, but when you introduce practical, they understand this topic better and they are able to think for themselves’.* (Physics teacher, Nigeria)

Commenting on the potential impact of practical work in improving student understanding of physics, an experienced school principal remarked:

*‘Well, to the best of my knowledge, it is designed to give the student a deeper knowledge of the subject matter in physics. It is not enough for you to know the theory but also the practical aspect of physics.....to confirm what you have taught the students is very necessary not only to pass exam alone but to widen the knowledge of students about the subject’.* (Principal, Nigeria)

An educationalist in one of the teacher training colleges had this to say.



*'In our college here, we got one idea that before teaching science either physics, chemistry or biology, student must know the saying that when I hear, I forget - when I see, I remember - but when I do, I understand..... so, practical helps the students to understand physics concept'. (Educationalist, Tanzania)*

Other stakeholders offered similar comments.

*'Practical brings about effectiveness in teaching, and also brings more understanding to what is being taught by the teacher'. (Head of Department, Nigeria)*

*'Practical activities brings about development of conceptual understanding and the learners are able to apply what they have learnt in theory'. (Educationalist, Nigeria)*

In addition to believing that practical work improves understanding of the theory, stakeholders in the study also believed that practical activities in physics help in reinforcing the theory by making the teaching and learning of physics more real to the student. The aim here appears to address the veracity of physics by providing a more direct physical context for the theory. A school principal offered this comment.

*'It is just to reinforce the theory that is been taught to the learners so that they can see the concepts that was taught in class and how it happens'. (Principal, South Africa)*

Comment from a physics teacher asserted that the teaching of theory without the necessary practical activities will be a fruitless effort. He commented:

*'Teaching practical physics helps to reinforce the knowledge of the learners because theory without practical or performing experiment is nothing'. (Physics teacher, South Africa)*

Other stakeholders offered similar comments.

*'We do practical work in order to relate it with the theory to see if they really correspond'. (Physics teacher, Ghana)*

*'Practical work is very important so that students can be able to relate the theory with the practical'. (Head of Department, Ghana)*

*'I think practical physics helps the learners to visualize and get to apply the knowledge they learnt in class because, if they can't see, I don't know how they will be able to connect to the real world with the theories'. (Physics teacher Ghana)*

*'Students can learn more when they see and use their senses to see what is happening around them. They learn better by seeing and doing physics experiments'. (Physics teacher, Tanzania)*

*‘Practical activities are very important to learners because they strengthen and consolidate the concept that you taught inside the classroom which made it easy for the learners to remember when they are sitting for any assessment’.* (Physics teacher, South Africa)

For many stakeholders, including some of those quoted above, there is an ambiguity about the precise intended aim of practical physics in facilitating broader learning but there was a clear view that it provided a broader curriculum service.

**(ii) Practical Specific Learning.** Many participants mentioned some form of skills development as one of the aims of practical work in physics. They believed that practical physics should enhance instrumental skills, data analysis skills, and mathematical skills. Other skills such as designing of experiments, handling and manipulation of experiments, innovation and creative thinking, observation and report writing were also mentioned. The following are some relevant comments offered by the participants.

*‘Practical helps the students to acquire necessary scientific skills and attitudes so that they will be able to perform better in the modern age of science and technology’.* (Educationalist, Nigeria)

*‘They (teachers) should know that practical helps students to understand abstract topics and are able to acquire skills for manipulation, mathematical skills etc’.* (Educationalist, Ghana)

*‘.....It helps students to develop mental and mathematical skills because if we go through the theory alone, it will not help the students understanding’.* (Physics teacher, Tanzania)

*‘Learners are able to use physics equipment with ease and much confidence when exposed to practical activities’.* (Physics teacher, South Africa)

*‘Practical work in physics is very essential as it is the foundation of technology and students are able to develop manipulative skills’.* (Physics teacher, Ghana)

*‘Practical work induces the learners to observe, make deductions and conclusions. It teaches skill and techniques and it is a way to instill the scientific methods and also broaden their field of experience and relate whatever they are doing to the world outside the lab’.* (Physics teacher, South Africa)

*‘Skills are acquired at all stages of experimentation. Practical involves stages, the first stage is observation, then recording and making Inference’.* (Physics teacher, Nigeria)

*‘Practical physics helps to develop in students necessary scientific skills and also to enhance creative thinking in the learners’.* (Principal, Nigeria)

*'Learners are able to acquire skills like accuracy in measurement and also skills of handling equipment, using equipment with much ease and much confidence when they are exposed to those apparatus'. (Physics teacher, South Africa)*

*'I think physics as a practical subject is designed to help students to observe a given phenomenon and develop scientific skills. Skills such as observation, measurement, recording, analysis, handling equipment and problem solving skills can be acquired'. (Physics teacher, Nigeria)*

*'Skills acquisition is one of the learning outcomes. At the end of the lesson, students should have acquired certain skills in measurement, observation and description'. (Lecturer, Ghana)*

**(iii) Exploration and Discovery.** Some of the stakeholders asserted that practical activities in physics should enable students to make new discoveries and verify facts and laws of physics. They argue that practical should be thought of as fact finding missions and that students should be able to discover as well as being told. A physics curriculum developer remarked:

*'Practical helps in breaking new ground and in exploration of new ideas'. (Educationalist, Ghana)*

A physics teacher also added this comment.

*'Practical is putting physics to action and it makes things real and not just seeing or writing about it.....practical helps students to investigate most of the laws in physics'. (Physics teacher, Nigeria)*

Another physics teacher said.

*'In science, we don't believe in theory alone, we believe in investigation and making deductions. We don't just make assumption, learners see things for themselves because seeing is believing.....they see what they were taught materializing in the physical realm and they now believe'. (Physics teacher, Nigeria)*

A female school principal argued that there is a disconnection between the schools and industry as students are not able to apply what they've learnt in practical physics. She commented thus:

*'Practical is very important because students can visualize what they've learnt in theory. In Africa, relationship between industry and schools is not very strong.....Students should see and touch what they've learnt'. (Principal, Ghana)*

Here are similar comments offered by other participants.

*'Practical work is very important because learners are able to apply physics concepts most especially in area of industry and they are able to visualize things for themselves'. (Physics teacher, South Africa)*

*'We don't tell them (students) what the outcome or the objective of the experiment will be .....They find it out themselves. It is a fact finding for them'.* (Educationalist, South Africa)

*'Doing hands-on activities, they (students) actually discover things for themselves rather than telling them this is what happen'.* (Head of Department, South Africa)

*'It (practical) induces the learners to observe, make deduction and conclusion'.* (Physics teacher, South Africa)

**(iv) Motivation.** About one third of the participants commented on the effect of practical work on student motivation. They asserted that it can help to arouse and sustain the interest of the students in physics. The following are comments offered by the participants.

*'Practical work is motivating and makes the learners appreciate what they are learning in the classroom'.* (Physics teacher, Nigeria)

*'Practical physics helps in arousing the interest of the learners and developing their curiosity, and helps them to investigate things around them'.* (Physics teacher, South Africa)

*'Practical work serves as a morale booster for the students to develop interest in physics as a subject'.* (Physics teacher, Ghana)

*'It (practical) is also designed to help the students to conceptualize a new approach to problem solving.....it will motivate the students and sustain their interest in physics'.* (Principal, Nigeria)

The direct physical nature of experimentation was seen as relevant to motivation. Several participants believed that student interest is stimulated by direct physical interaction with equipment, by sight and touch.

*'It is good to teach learners, but they are better off if they see things done in a real sense, this will go a long way in developing their interest in physics'.* (Head of Department, South Africa)

*'Practical physics is very interesting to the students because of what they can see and touch.....some of the students even prefer to stay in the laboratory throughout the day doing practical than to stay in the theoretical class.....'.* (Physics teacher, Nigeria)

Several participants asserted that practical work was aimed at helping learners to relate what they've learnt in physics to what goes on in the natural and industrial environment. By carrying out practical work, they gain insight and are more able to solve life problems.

*'We don't only learn physics but should be able to relate physics to our environment with the help of practical activities'.* (Educationalist, Tanzania)

*'Practical is very important because students can visualize what they've learnt in theory. In Africa, relationship between industry and schools is not very strong.....Students should see and touch what they've learnt'. (Principal, Ghana)*

*'It is a way to instill the scientific methods and broaden their field of experience and relate whatever they are doing to the world outside the lab'. (Physics teacher, South Africa)*

*'Practical helps learners to connect to the real world of life'. (Head of Department, South Africa)*

*'Students acquire knowledge which can be applicable in our real world and typical environment. They can relate life to what they learnt in school...'. (Science teacher, Tanzania)*

*'We want to make the students to be aware of what physics can really do in their life. It enables the student to use physics in their daily life'. (Senior Official, Tanzania)*

Several of the above comments appear to link motivation to the future value of practical physics skills and knowledge. Economic value was raised more explicitly by some interviewees.

(v) **Economic Needs and Priorities.** Some of the participants relate skills acquisition to the economic needs and priorities of the individual and society as a whole. They believed that students can contribute to the development of a country if he/she acquires the necessary skills. A support staff member offered this comment.

*'It (practical physics) is very important because that is where they begin.....students are able to acquire knowledge in making use of tools and how to manage and produce tools'. (Educationalist, Tanzania)*

He stated further:

*'Physics education should be hands-on so that, after graduation, students should be able to set up their own industry and use physics to improve their life'. (Educationalist, Tanzania)*

A physics lecturer also offered this comment.

*'Yes, I believe that practical is very important because learners are able to build equipment for themselves and thereby developing the technology of our country.....it is essential that skills in using and managing equipment is developed'. (Lecturer, Tanzania)*

Other participants commented similarly.

*'Practical work in physics is very essential as it is the foundation of technology and students are able to develop manipulative skills'. (Physics teacher, Ghana)*

*‘.....Engaging the learners in practical activities will enable them to contribute their quota to national development because any country that does not embrace science cannot move forward’.*

(Physics teacher, Nigeria)

*‘Practical physics will help students to contribute their quota to national development because any country without science will not move forward’.* (Physics teacher, Nigeria)

### 6.1.2 What is the present status of practical physics education in African schools?

In this section, the qualitative findings about present practice are presented. Analysis of the stakeholder interviews revealed the views of the stakeholders on (i) the achievements of the students, (ii) the available resources and the fit of practical work to the broader curriculum. They discussed (iii) the lack of teaching time available for practical, and (iv) the nature of the practical work. A common view was that physics teaching is ‘minds on’ rather than ‘hands on’ and that practice is oriented towards preparing the students for examination. Given this priority, teachers tend to only engage the students in practical activities when their final examination is approaching. It was suggested that (v) teacher attitudes to the performance of practical work are often negative. The themes used to categorizes the responses are given in Table 6.2

**Table 6.2** Themes and numbers of respondents commenting on present practice. The participants made 87 separable comments in total on present practice.

Country (Number of interviewees)	Ghana (15)	S. Africa (21)	Nigeria (12)	Tanzania (18)	Total (66)
<b>Theme</b>					
<b>(i) Student performance</b>	10	12	10	2	34
<b>(ii) Resources and facilities</b>	6	3	3	4	16
<b>(iii) Lack of teaching time</b>	5	2	5	2	14
<b>(iv) Nature of the practical activities</b>	3	2	2	3	10
<b>(v) Attitude of teachers</b>	2	4	2	5	13

**(i) Student Performance.** There were diverse views on the performance of the students in practical activities in physics. Some argued that students achieve little while some are pleased with their performance. There were also comments on students’ inability to identify physics equipment and to set up experiments. Some participants said that students are able to do practical work but not the associated mathematics.

A university lecturer argued that the lack of skills in identifying practical physics equipment and poor mathematics background is not limited to the high school students but also extends to the university. He offered this comment.

*'In the university here, we asked students to differentiate between a resistor and a capacitor but unfortunately, they couldn't. Most of them are lacking skills of identifying physics equipment. I also think that poor background in mathematics is really affecting our students even at the graduate level'.* (Lecturer, Tanzania)

Participants offered the following range of comments.

*'In this school we have talented girls. If you give them instructions, they follow without any problem but they still fail to apply mathematical knowledge to physics'.* (Physics teacher, Tanzania)

*'I am quite pleased about my students' performance but am not satisfied. We are not where we want to be. If you compare our matric physics result to the schools in the surroundings, they are far below us. They got 10% and 30% but we got 80% pass rate. However, the main issue is not only to get the passes but the quality passes and those are the two issues we are looking on right now'.* (Principal, South Africa)

*'I think they are performing well most especially in external examination but still face a lot of challenges due to fear of failure in the aspect of plotting graph and making deduction from the graph'.* (Physics teacher, Nigeria)

*'Their performance is quite low. What the government is advocating in terms of the content and the practical experience the learner should go through is not enough. Looking at grade 12 physics syllabus, there is only one recommended practical in a term which is not enough. The issue of practical is not really emphasized at matric level'.* (Physics teacher, South Africa)

*'In other years, we used to perform above 70% but last year, for the first time, will drop to 33% which is far below our expectation'.* (Head of Department, South Africa)

*'We used to do well but unfortunately, our result drops last year. I'm quite worried about the quality of the physics result because many students failed in grade 12 and also in the other grades'.* (Principal, South Africa)

*'The basic problem for our students is the mathematics aspect of the practical and once the question that involves mathematics is there, then the problem comes'.* (Head of Department, Tanzania)

*'Our students understand better when it comes to practical physics but are still weak in the mathematical area and the plotting of graphs'.* (Physics teacher, Ghana)

*‘Even without performing the experiment, some students use formula and make necessary deductions. They do calculation and plot the graph and they will pass’. (Educationalist, Ghana)*

*‘They perform very well when they are taught. However most students find it difficult to operate apparatus because of fear of failure’. (Principal, Ghana)*

*‘Students hardly acquire any skills, they just get data for the experiment without the main practical session’. (Educationalist Ghana)*

*‘In terms of physics result there is improvement but I think the students are still lagging behind in representing their observations on the graph. I went for monitoring during the examination period and I discovered that after taking readings of electricity and mechanics experiments, the students find it difficult to present their ideas on the graph sheet, finding the slope and getting deductions’. (Educationalist, Nigeria)*

*‘Students have been doing fine in practical physics since most of the teachers are now examiners. They know what is required to pass practical physics but the plotting of graphs and the calculation aspect is still a big problem for the students. They are always afraid of calculation’. (Educationalist, Nigeria)*

*‘Student can write the theory and pass.....with the little practical that we had with the students, I think they are doing well’. (Head of Department, Ghana)*

*‘They are not doing very well because our students failed woefully in the last matric examination probably due to lack of exposure to practical activities from grade 10’. (Head of Department, South Africa)*

*‘Well, the students’ performance is nothing to talk about.....They are not good in practical due to lack of exposure and this is really affecting their performance’. (Physics teacher, Tanzania)*

**(ii) Resources and Facilities.** The participants commented on the lack of practical physics equipment, large class sizes and in some cases, the shortage of human resources as some of the issues that influence the present practice. Some of them argued that the inadequacy of apparatus hinders them from engaging the students in practical activities.

*‘There is no equipment to perform some experiment.....and lack of laboratory technician to support the teachers’. (Head of Department, Ghana)*

*‘We don’t have resources to cater for the large number of students’. (Physics teacher, South Africa)*



*'There is a shortage of apparatus.....sometimes we want to perform a certain practical but we find out that the equipment for this experiment are not there'. (Physics teacher, Ghana)*

*'There is no functional laboratory and we do experiment in the normal classroom'. (Physics teacher, South Africa)*

*'We have a large class here with few equipment which makes practical engagement a problem and also lack of exposure'. (Physics teacher, Tanzania)*

*'.....practical is somehow done but not well done for many reasons. First, of all the subjects we teach here, physics is the leading subject with higher shortage of teachers.....we don't have resources and thus the teaching is basically theoretical'. (Senior official, Tanzania)*

*'Actually, because we are not doing well in practical physics, the number of students offering the subject has reduced drastically due to lack of facilities. Those choosing to offer physics in Form III and IV are very few.....They find the subject boring due to lack of exposure to practical work'. (Principal, Tanzania)*

Class size was raised by several respondents. This may be a resource issue but may also involve the practicalities of class management.

*'Classes are very large and this makes it difficult for the entire group of students to be engaged in practical activities'. (Head of Department, South Africa)*

*'.....there are roughly 60 students in my class and we are really finding it difficult to do any practical work'. (Physics teacher, South Africa)*

**(iii) Shortage of Time.** Some of the stakeholders asserted that there is lack of sufficient time for practical work due to the volume of work to be accomplished and the nature of the school timetable. Here are some of the comments offered.

*'Only 35 minutes is allocated for practical work in physics in my school which is not even enough for the students to carry out any experiment'. (Physics teacher, Nigeria)*

*'I only teach practical physics when an exam is near because of time due to the contents to be covered in the curriculum'. (Physics teacher, Nigeria)*

*'Time is a major problem for me to lead the students in hands on activities. Looking at our timetable, there is no room for practical physics, so I have to create the little time at my disposal which might not be adequate'. (Physics teacher, Nigeria)*

*‘.....we have the recommended and prescribed practical embedded in the curriculum but because of limited time and the amount of content the teacher needs to cover, it has really been a major problem’.* (Educationalist, South Africa)

*‘The time is limited, the curriculum is very much and we have a lot of topics to cover. So, we adopt mostly the theoretical method’.* (Physics teacher, Tanzania)

*‘.....Practical should follow the theory but unfortunately, there is no time for us to practice due to the nature of the curriculum’.* (Physics teacher, Ghana)

*‘Shortage of equipment, lack of funds to schools, limited time for practical activities and overloaded curriculum’.* (Physics teacher, Ghana)

*‘.....I have 56 (students) in a single class which make practical difficult and the school timetable doesn’t give room for practical’.* (Principal, Ghana)

**(iv) Nature of the Practical Activities.** Some of the stakeholders believed that practical work is confined to meeting examination requirement. Also, there were views that the recommended practical activities are not adequate.

*‘Students are trained to write exam and pass.....there is practical work in the curriculum but seen as a means to pass exam’.* (Head of Department, Ghana)

*‘.....practical work is the requirement of examination body.....the teachers are just teaching the topic and after two years, they do the experiment.....that is practical work to them (physics teachers)’.* (Educationalist, Ghana)

*‘Teachers teach for results and how the student gets the result nobody cares because student must pass at all cost and teachers are taking short cuts so that students can pass their exam’.* (Lecturer, Ghana)

*‘It is quite unfortunate because of my experience.....shows that teacher is teaching only theory and only teach practical during the exam. This attitude limits the knowledge of the students to what is supposed to be learned in practical physics.....’.* (Principal, Nigeria)

*‘Even without performing the experiment, some students use formula and make necessary deduction. They do calculation and plot the graph and they will pass’.* (Educationalist, Ghana)

*‘They only teach the theory part and hope to do the practical at the end of the year when students will be preparing for exams. They are mostly focusing the last classes for the exam but, for those that*

*are not preparing for examination, they are only doing the theory part and this has been a major problem'. (Educationalist, Tanzania)*

*'We only do practical when they are about to write exams which is in form IV'. (Physics teacher, Tanzania)*

*'Well, I think there is a disjunction between theory and practical. In some cases, practicals are done because they have assessment in view'. (Educationalist, South Africa)*

*'Their performance is quite low. What the government is advocating in terms of the content and the practical experience the learner should go through is not enough. Looking at Grade 12 physics syllabus, there is only one recommended practical in a term which is not enough. The issue of practical is not really emphasized at matric level'. (Physics teacher, South Africa)*

**(v) Attitudes of Teachers.** Several educationalists believe that most of the physics teachers don't have the skills required to teach the practical aspects of physics due to deficiencies in the training they have received. They opined that the teachers only teach the theory and are afraid to deal with the practical aspect because they have never been exposed to practical activities themselves. The following are examples of comments made.

*'I could say there is a challenge of practical knowledge on the part of the teachers. It is garbage in - garbage out. In the training that is given to teachers while in O' level and A' level and subsequently at the Teacher training college, there is package of theory, then practical. So, when it comes to practical you only give what you have and you can't give what you don't have'. (Senior official, Tanzania)*

*'The main problem is that teachers themselves don't have skills to teach the practical aspect of physics though they might be good in theory'. (Educationalist, Tanzania)*

*'Schools currently recruit people who have done part of science and not physics teachers. Such people might not have what it takes to handle practical activities in physics'. (Senior official, Ghana)*

*'Handling practical physics in schools entails professionals and I want to say that most of the teachers teaching physics these days are not professional and that makes the teaching of the subject boring to the students and when a blind is leading the blind, they all fall into the pit'. (Physics teacher, Nigeria)*

*'Most of the teachers don't have the needed background in education and when they come to school they only do the theory and are afraid of practical work because they've never been exposed to practical themselves. In my case, I did mostly physics in the university but I did not do chemistry and*

*whenever I have to teach chemistry, I feel very reluctant because I don't have much confidence'.*

(Physics teacher, South Africa)

*'My teachers are struggling to teach the subject.....also, the style (teaching approach) of the teacher matters a lot and their attitude.....teachers sometimes don't know what to teach'.* (Principal, South Africa)

*'.....Some of the new entrants into the teaching profession are not really exposed to practical activities'.* (Physics teacher, Tanzania)

### 6.1.3 What are the critical factors determining success and failure in delivery of the intended curriculum?

In this section, participant's views about the factors affecting the teaching and learning of practical physics are presented. Three broad themes were identified in the responses; (i) resources and facilities, (ii) the physics curriculum, and (iii) the attitude and motivation of both teachers and students. The large majority commented on the issues of resources, a theme which includes both human and material resources. Several interviewees believed that the physics curriculum is overloaded in content and some commented on the prevalence of a small set of often dull and outdated experiments. A belief that physics is only appropriate for an elite group and lack of assessment of practical skills were also raised by the participants. A number of interviewees suggested that teachers find it difficult to create good quality practical learning experiences. There is a lack of adequate professional training and motivation is often lacking. A numerical breakdown of the themes raised is provided in Table 6.3. It is not surprising that the comments on critical factors rehearse views that are similar to those expressed in relation to current practice.

**Table 6.3** Themes and numbers of respondents commenting on critical factors. The participants made 123 separable comments in total on the critical factors.

Country (Number of interviewees)	Ghana (15)	S. Africa (21)	Nigeria (12)	Tanzania (18)	Total (66)
Theme					
(i) Resources and facilities	14	20	11	14	59
(ii) The physics curriculum	8	9	6	6	29
(iii) Attitude and motivation	7	7	9	12	35

(i) **Resources and Facilities.** A large majority (59 out of the 66) stakeholders talked about the lack of both human and materials resources to cater for the large number of students. They mentioned that schools are not well-equipped, and there is; lack of laboratory assistance support, shortage of physics teachers, and large class sizes. In some cases, theft of equipment and issues of unused equipment are major challenges faced by physics teachers in the delivery of effective practical physics lessons. The participants offered the following comments.

*‘Lack of equipment is one factor. It is even difficult to teach physics at the teachers training college here because of limited physics facilities. Most high schools do perform more physics experiments than we do. Teachers are not employed as there are few teachers to teach physics. Also there is no laboratory technician to assist physics teacher’.* (Lecturer, Ghana)

*‘Most of our apparatus are broken down and no longer functioning. I have 56 students in a single class which makes practical difficult’.* (Principal, Ghana)

*‘The major challenge that I have is the way some teachers do disturb me in the lab. There is a problem of accommodation. We have a separate physics lab but you discover that the chemistry and the biology teacher will come there to teach their students. Although, they have their own laboratory it is no longer functioning because there are no chairs and tables’.* (Physics teacher, Nigeria)

*‘Most of the apparatus needed for the practical work are not readily available. We only have few equipment to perform experiment on mechanics while other experiments are neglected because we do not have the required equipment. Also, it is very difficult to carry out formative evaluation in practical physics due to the large population of students’.* (Physics teacher, Nigeria)

*‘Lack of apparatus and lack of qualified teachers who are real physics educators. Government has been recruiting engineers, biologists etc. to teach physics’.* (Educationalist, Nigeria)

*‘Well, the major problem here is the availability of teachers to teach the subject. We only have a physics teacher to teach from Form 1 to Form 4. Also, we don’t have a special room for doing practical as we only use the classroom with virtually no equipment’.* (Principal, Tanzania)

*‘There is no laboratory technician. We have to make the practical arrangement and with the volume of our work, it is really very stressful’.* (Physics teacher, Tanzania)

*‘We have a very large class here with few equipment which makes practical engagement a problem. Sometime, we want to perform a certain practical but we find out that the equipment for this experiment are not there. So, it is a big challenge to me’.* (Physics teacher, Tanzania)

*'We have a school with 500 students and only one physics teacher. So with huge workload concentration, the preparation is very inefficient and then there is no laboratory. Here we have 49 schools out of which 23 are government schools, but very few have a physics laboratory, maybe 3. The number of secondary schools has been growing rapidly and there is proportional increase in student population. Subsequently, if schools didn't have laboratories, they are not expected to have equipment'. (Senior official, Tanzania)*

*'The numbers of our learners is a big problem, almost 10 students per group during practical sessions while some of them will be idle doing nothing. Using the classroom as a laboratory is another major problem coupled with lack of experienced teachers to teach physics and insufficient equipment'. (Head of Department, South Africa)*

*'I think the most challenge is the huge number of students in class. There are roughly 60 students in my class and we are really finding it difficult to do any practical work'. (Physics teacher, South Africa)*

*'There is lack of teachers who are qualified in the teaching of physics or chemistry. Some of the teachers are having background in zoology etc...'. (Educationalist, South Africa)*

*'We've been having shortage of physical science teachers. Single physical science teacher from 2011 to 2013 basically for grade 10 to 12. We also had a big growth in student numbers from 183 in 2010 to 560 in 2015. The resources is not much as we only have a single lab for physical sciences and life science and we have to convert our classroom to physics lab''. (Principal, South Africa)*

*'Looking at my school which is rural, we have a lot of problems. If I take you to our lab, you will write second thesis on it. We have problems with thieves. They stole even the alcohol in the chemistry lab and even if we improve the lab, after a month, it is vandalized. It is supposed to be well equipped laboratory but it is not. Until we improve our security in this school, we will never have any equipment in the laboratory and is affecting the learners. There is no equipment, and so we rely more on the theory'. (Head of Department, South Africa)*

*'The main challenge is the human resources. I once trained teachers around 30 schools and all those schools when you get there, you ask the principal what is happening, you will see them complaining about the apparatus but when you go to their offices, you find that these equipment are there but they are not in use. Sometimes the teachers may not even know that those things were there and even when they are aware, they don't know how to use them'. (Lecturer, South Africa)*

*'Availability of resources for teachers to perform practical work is another problem. Although, we are trying to make equipment for the schools in form of boxes but the danger is, if you go back to those*

*schools, at the end of the year, those boxes are still sealed and they are not used and the teachers said they have not been trained on how to use it'. (Senior official, South Africa)*

**(ii) The Physics Curriculum.** Some of the teachers interviewed (29 of 66) complained about the physics curriculum being overloaded with content giving limited opportunity to engage the learners in practical activities. There were also comments on lack of sufficient time and lack of assessment of practical activities which is critical in its influence on all aspects of effective delivery. One of the physics teachers said:

*'The curriculum is overloaded with too much content and I teach the whole school physical science and to be very honest, I can't manage or cope with setting up experiment for the whole classes'. (Physics teacher, South Africa).*

A school principal commented on overload and other deficiencies in a newly introduced curriculum. He remarked:

*'.....Curriculum Assessment Policy Statement (CAPS) started 2 years ago and the teachers are saying that the curriculum is so full and (they) need a lot of time to accomplish it' (Principal, South Africa)*

Some teachers also asserted that there is lack of sufficient time for practical work due to the volume of work to be accomplished and the nature of school timetable. Here are the comments offered.

*'Only 35 minutes is allocated for practical work in physics in my school which is not even enough for the students to carry out any experiment'. (Physics teacher, Nigeria)*

*'I only teach practical physics when an exam is near because of time due to the contents to be covered in the curriculum'. (Physics teacher, Nigeria)*

*'Time is a major problem for me to lead the students in hands on activities. Looking at our timetable, there is no room for practical physics, so I have to create the little time at my disposal which might not be adequate'. (Physics teacher, Nigeria)*

*'Another issue is not covering of the physics syllabus from junior school which accumulated to the next level'. (Lecturer, Ghana)*

*'The content of the syllabus is voluminous..... teachers thereby pay more attention to the theory than the practical to complete the syllabus'. (Head of Department, Ghana)*

*'Curriculum Assessment Policy Statement (CAPS) is structured with less official pressure to do practical work of any form than in the past. Practical physics is not a South African reality and there is a fundamental flaw in the way science is taught as a school subject'. (Senior Official, South Africa)*

According to some of the stakeholders, one of the major challenges to effective teaching and learning of practical activities in physics is the lack of practical physics assessment. A senior physics educationalist in South Africa asserted that teachers are just expected to do some prescribed practical work but the exam itself doesn't make provision for assessing the practical skills of the learners. According to him, the teachers might not engage the learners in any practical activities because he/she is quite aware that it is not going to be assessed in the exam. He commented:

*'When you look at some countries in Africa like Ghana and Nigeria, there is formal assessment when it comes to practical work but, in South Africa, teachers are just expected to do some prescribed practical work but exam itself doesn't make provision for assessing the practical skills of the learners. So, you find out that the teacher might actually run away from this important aspect because he/she knows that it is not going to be assessed in the exam or there is no question in the formal exam paper that specifically assesses learners' practical skills'.* (Senior official, South Africa)

A school principal also expressed his displeasure at the lack of assessment of practical skills. According to him, teachers don't like to waste their time engaging students in practical because practical doesn't contribute much to the overall performance of students in physical sciences. He remarked:

*'It is very disheartening for teachers to do all the theory and the practical and, at the end of the term, seeing that the practical only carry 5 marks on a paper of 150 marks. We put much emphasis on the theory because there is no practical exam'.* (Principal, South Africa)

**(iii) Attitude and Motivation.** Many participants (35 of 66) commented on attitudinal issues and motivation. Some remarked that physics teachers are not adequately supported and are poorly remunerated by the government. They said government is paying lip service to science education and in most cases is not interested in the welfare of teachers. There were also comments on the professional skills and the level of developmental training of teachers which is widely believed to be inadequate. Here are representative comments offered on this theme.

*'They said they are restructuring the curriculum but it is quite unfortunate that the powers that be are people who have no interest in science and who never do science in school and are even having problem with science teachers. They don't see any need in supporting the teacher'.* (Principal, South Africa)

*'Teachers are poorly paid and unless they treat them at par with other professions, the best minds will still be opting for careers that will fetch them money and the end result is that will end up with quantity and not quality'.* (Educationalist, South Africa)



*'Funding for science is not enough and (this leads to) lack of motivation for teachers'. (Principal, Ghana)*

*'There is no motivation from the government and what we do is to motivate the physics teachers in our own way by paying him a token from the school purse to motivate him'. (Principal, Tanzania)*

*'Also, there is no motivation, most teachers are just teaching because there is no alternative. They are not enthusiastic on the job. I think these are some of the challenges'. (Educationalist, Tanzania)*

*'If teachers are well motivated, they can wait after school hours till evening to perform practical for students. However, teacher's allowance is very ridiculous. We have some chemistry practical experiment that are very hazardous and also in physics. Another problem is that those in authority are not having much interest in science, most especially when the school administrator is not into science, he/she may not see any reason for equipping the laboratory'. (Educationalist, Nigeria)*

*'Teachers are having the right attitude to teaching but there is lack of motivation in terms of science allowance and other means of motivating teachers'. (Educationalist Nigeria)*

*'There is lack of motivation for teachers from government in terms of improved science allowance which can boost their morale'. (Principal, Nigeria)*

*'Those that are not interested in science are the decision makers and they will go against the idea you are bringing to the table. My fear is that those who have the vision are on their way out and those taking their place are people who have been taught just to memorize'. (Educationalist, Tanzania)*

Many educationalists point to the fact that most of the physics teachers don't have the skills required to teach the practical aspect of physics due to the training they have received. They opined that the teachers only teach the theory and are afraid to deal with the practical aspect because they have never been exposed to practical activities. It must be noted that most of the comments made on the 'attitude of teachers' in research question two are also relevant in this section. Some are repeated here. The following are examples of comments made.

*'Teachers are not taught practically and don't have what it takes to teach the subject, they are not professionally sound'. (Head of Department, Ghana)*

*'Most of the teachers are not skillful in handling the subject and when they come to school, they only do the theory and are afraid of the practical aspect because they've never been exposed to that themselves'. (Principal, South Africa)*

*'I could say there is a challenge of practical knowledge on part of the teachers. It is garbage in-garbage out. In the training that is given to teachers while in O' level and A' level and subsequently at the Teacher training college, there is package of theory, then practical. So, when it comes to practical you only give what you have and you can't give what you don't have'. (Senior Official, Tanzania)*

*'The main problem is that teachers themselves don't have skills to teach the practical aspect of physics though they might be good in theory'. (Educationalist, Tanzania)*

*'One of the challenges that I see is incompetence on the part of the teachers in the sense that, during their training, they are not well grounded in the practical part of the subject which has really influenced their teaching and their level of professionalism'. (Educationalist, Tanzania)*

*'Schools currently recruit people who have done part of science and not physics teachers. Such people might not have what it takes to handle practical activities in physics'. (Senior official, Ghana)*

*'Handling practical physics in schools entails professionals and I want to say that most of the teachers teaching physics these days are not professional and that makes the teaching of the subject boring to the students and when a blind is leading the blind, they all fall into the pit'. (Physics teacher, Nigeria)*

*'Most of the teachers don't have the needed background in education and when they come to school they only do the theory and are afraid of practical work because they've never been exposed to practical themselves. In my case, I did mostly physics in the university but I did not do chemistry and whenever I have to teach chemistry, I felt very reluctant because I don't have much confidence'. (Physics teacher, South Africa)*

*'Most of the science teachers usually find it difficult to handle physics experiment themselves and this is a complicated problem'. (Lecturer, South Africa)*

Most of the stakeholders interviewed said there is no in-service training for them to improve their teaching. The comments describe a mutually reinforcing system in which there is little commitment to improvement at the level of the teachers and little opportunity for development provided by the authorities. This may be a by-product of the priority of increasing teacher numbers to deal with an increasing school population. The following are the comments offered to support their claims.

*'There are training sessions but they are not adequate. The training time is so short that you cannot gain anything'. (Physics teacher, Tanzania)*

*'The bureaucracy over there, think they want to change system. They change the syllabus but the teachers are still the same who pass through the old system'. (Educationalist, South Africa)*

*'Curriculum and Assessment Policy Statement (CAPS) is restructured but it is very hard to change the way science is being taught. Some schools don't look different today than it looks about 28 years ago and many teachers are the same'.* (Lecturer, South Africa).

*'There is lack of seminars, training and workshop for science teachers'.* (Science teacher, Tanzania)

*'(There is) limited in-service training to equip the teachers on how to use physics equipment'.* (Physics Teacher, Ghana)

*'Most of the teachers lack orientation as they still use their old notes to teach the students'.*  
(Principal, Ghana)

*'Teachers are not exposed to practical training and are afraid to conduct practical physics'.*  
(Educationalist, Tanzania)

Apart from motivation, the attitude of the students to practical work and physics in general also influences success in delivery. Some stakeholders were of the view that learners perceived physics and mathematics as being difficult because they think these subjects are only meant for certain people and that only the academically gifted will attempt physics. This issue of appropriateness was extended by a school principal who said that students don't see physics as an important subject due to a belief that the subject is only meant for the 'white' population. According to him, this belief is still having a significant effect on the learners and explains why very few of them have an interest in science. He remarked:

*'In South Africa, learners see physics and mathematics as a difficult subject and because it is viewed like that, it is only the brave and those that see themselves as gifted or clever will attempt physics. It is not seen as an important subject. We are 20 years into democratic settings but what was indoctrinated in the past is still holding us back. We see certain things for certain people and we don't claim they are for us. In the past, there are theories that the black cannot do mathematics and science but may be good in art subjects and we are still battling with that conception of ourselves'.*  
(Principal, South Africa)

A university Lecturer also offered this comment.

*'There has been a lot of inequality happening in this country and the white kids already know all things, but our kids are still afraid'.* (Educationalist, South Africa)

A retired physics teacher in Ghana was also worried about the low number of female students showing interest in physics and he suggested the need to sensitize the female students to the option of pursuing a career in physics. He commented as follows.

*‘Physics teachers are least in number when it comes to workshop and even worse is the percentage of girls studying physics in the university.....we must try to organize workshop for the girls so that they can create interest and want to study physics’. (Educationalist, Ghana)*

A senior official in the ministry of education remarked:

*‘School currently picks people who have done part of science but are not physics teachers. Also, it looks like people allow the fear of mathematics to go deep into them. Girls are not into science due to the phobia of science .....We have 10 students for art against 2 students for science’. (Senior official, Ghana)*

#### **6.1.4 How can the teaching of practical physics in African schools be improved in the short and long run?**

Participants offered a range of views on how the teaching of practical physics might be improved. Many were proposing remedies for the limitations discussed above. They suggested: (i) building more laboratories with modern equipment and having a specialist in practical physics to teach the students, (ii) reducing the physics curriculum, strengthening practical assessment and having students with good background knowledge in physics at the elementary stage content, and (iii) addressing attitude and motivation by, for example, improving professional training for physics teachers, increasing pay and improving conditions. Some comments offered other possibilities, e.g. (iv) introducing regional collaboration, and (v) teaching through the use of ICT. Table 6.4 provides a numerical overview of the suggestions collected into broad themes.

**Table 6.4** Themes and numbers of respondents commenting on improvement. The participants made 139 separable comments in total on improvements in practical physics teaching.

<b>Country (Number of interviewees)</b>	<b>Ghana (15)</b>	<b>S. Africa (21)</b>	<b>Nigeria (12)</b>	<b>Tanzania (18)</b>	<b>Total (66)</b>
<b>Theme</b>					
<b>(i) Resources and facilities</b>	14	21	12	12	59
<b>(ii) The physics curriculum</b>	7	4	–	6	17
<b>(iii) Attitude and motivation</b>	14	12	12	13	51
<b>(iv) Regional collaboration</b>	–	1	–	2	3
<b>(v) Learning technologies</b>	3	6	–	–	9

**(i) Resources and Facilities.** Most of the participants (59 of 66) remarked that there is need for additional human and material resources for effective teaching and learning of practical physics. They said there should be a separate laboratory for practical physics and also state of the art equipment. Recruitment of more physics teachers and the possibility of separate teachers for practical physics were also suggested. More funding for science education was advocated. Here are a few examples of relevant comments.

*‘For effective teaching of practical physics, there must be a lab in which you can operate in and we also need modern laboratory equipment’. (Principal, South Africa)*

*‘Building a state of the art laboratory where both learners and teachers can learn. We want the students to start playing with real data and know that it is easy to discover something for themselves. We still need more equipment to do more electronics experiments so that our students can be innovators tomorrow’. (Professor, South Africa)*

*‘Giving teachers all that is needed to the prescribed experiment and having a dedicated laboratory specifically for physical science’. (Physical Science Teacher, South Africa)*

*‘We are making conscious effort to have at least 3 science teachers in each of the 600 Senior High Schools. Government should also allocate more funds for science education’. (Senior Official, Ghana)*

*‘Having access to practical physics equipment and conducive environment will go a long way in improving my teaching’. (Physics teacher, Ghana)*

*‘If we are to do better, we need more teachers in the subject. Presently, there are 80 practicing teachers from the training college here in my school and none of them specializes in physics. Building physics laboratory and buying equipment is very important’. (Principal, Tanzania)*

*‘We have too much work because we the science teachers are few in numbers compared to others in arts and social sciences. More science teachers should be employed to reduce our work load’. (Science teacher, Tanzania)*

*‘Our president has emphasized that each school should build a laboratory but, if the laboratory is built and we don’t have equipment, it will be a big problem. To me, equipment is more important than the laboratory because you can take them to the class. If we have a good adviser, we can get the equipment and use the classroom to do whatever we want but I don’t know who is advising the president because he is not a scientist. So, if government could actually buy equipment then that could motivate the students and the teachers to do practical’. (Lecturer, Tanzania)*

*‘Provision of adequate materials especially in electricity because most of the materials for electricity experiment in our school are no longer functioning and are outdated’. (Physics teacher, Nigeria)*

*‘Having a conducive environment, standard laboratories with tables, chairs, and modern equipment and also well trained teachers to be employed to teach physics’. (Principal, Nigeria)*

Some of the participants interviewed suggested the possibility of an additional teacher who would be in charge of practical activities in physics as they believed it would help to lessen the burden of the physics teachers whose main focus would then be on the theory. A head of science in one of the schools visited offered this comment.

*‘I think the Department of Education should employ somebody to specialize in practical activities like is being done in higher institution’. (Head of Department, South Africa)*

A physics teacher also suggested that government should employ separate physics teachers who will be devoted to the teaching of practical physics. He remarked:

*‘I am not sure if this is possible but it is better for government to employ somebody who will be teaching the practical aspect which I think will be perfect’. (Physics teacher, South Africa)*

Another head of a science department also suggested that it would be a welcome development if the community or government could arrange and pay for a separate physics teacher who would help fill in the gap between the practical and the theory.

*‘If the community can come up with tutors and also the government, they may be used to fill in the gap and hope that the parent could pay for it’. (Head of Department, South Africa)*

**(ii) The Physics Curriculum.** A significant number of participants (17 of 66) commented on the design of the physics curriculum. A reduction in the physics curriculum content to create more room for hands-on activities was a common suggestion but there were also a number of stakeholders who advocated formal assessment in practical physics and action to ensure that students should have solid background knowledge at the elementary level.

A teacher trainer who lectures in physics in one of the colleges stated that there should be a way of incorporating testing alongside the theory to promote teachers who wanted to do practical. According to him, students need to be assessed after each practical activity and teachers should not wait till the learners are in their final year before assessment is carried out. He remarked:

*‘We need to improve the way we test our student in practical work..... even if the materials are available and learners are not tested and you only wait till the students are in Form IV and then you*

*introduce them to practical, they won't see the importance of doing practical and this will remain a big problem'. (Lecturer, Tanzania)*

He added that:

*'..... Experiment should prepare students for life but (in reality) it only prepare them for exams. There should be a way of incorporating testing (of practical physics) alongside the theory to promote teachers who wanted to do practical'. (Lecturer, Tanzania)*

A senior official also offered comments on the need for assessing practical physics. According to him, experiment must go beyond encouraging teachers to do practical and that there should be a practical examination.

*'Teachers do get away without engaging in practical activities because there is no question in the formal exam paper that specifically assesses learner's practical skills. Experiment must go beyond just encouraging teachers to do practical work. They should find a way of creating assessment opportunity for the practical aspect (examination) so that we can be at the same level with other developed countries. I think this will make it compulsory for the teachers to perform practical'. (Senior official, South Africa)*

A physics teacher added this comment.

*'If there could be a practical examination introduced to the matric level, this can go a long way'. (Physics teacher, South Africa)*

Some participants were of the opinion that the learners need to be well grounded at the elementary level. There were suggestions that learners should do additional theory and practical work at the lower level so that there could be a reduction in physics content at the higher level. According to some of the participants, gaining background knowledge of physics at the early stage would create room for more practical work in secondary schools. The following comments were offered to support such views.

*' Well, the priority now is to go back to the primary level and train the physics teachers so that they can equip the pupils and build their confidence in practical activities both at the primary level and also when they get to the secondary school. We have to start at the foundation'. (Educationalist, Tanzania)*

*'We normally receive students from different wards with few having the ability to learn. It is better if students are well grounded at the elementary level so that it will be easy for us to continue with them when they are here'. (Physics teacher, Tanzania)*

*'Science is a difficult subject because learners come in with gaps in their background knowledge. And it is quite sad that you find out that they don't know anything as teachers have to go back spending time to bridge the gap of practical and theoretical knowledge they should have gained earlier'.* (Head of Department, South Africa)

A school principal suggested a change to the physics curriculum to be more practically oriented.

*'If I were up there, I would change the curriculum to be more practical and I think the duration of school should be elongated. They said it is three years but it is actually two and half years with a lot of activities'.* (Principal, Ghana)

This idea was also supported by a physics teacher.

*'.....the physics curriculum content needs to be reduced to enable us to finish it before the students start writing their final exams'.* (Physics teacher, Ghana)

Another physics teacher also wanted the physics curriculum to be reviewed.

*'I also think the curriculum need to be restructured to accommodate more practical activities'.* (Physics teacher, Ghana)

**(iii) Attitude and Motivation.** A larger majority of the participants (51 of 66) highlighted the need to improve attitudes and motivation. They suggested that physics teachers should develop a positive attitude towards the teaching of practical work along with the theory, and that teachers don't need to wait till the final examination is approaching before engaging the learners in practical activities. Improvements in teacher motivation should be both encouraged and required. Professional training should be provided to nurture practical skills in physics teachers. A national trainer remarked:

*'Teachers should change their mind that they need sophisticated equipment before they can teach the students. They must think of locally made materials which are of low cost to make simple equipment for demonstration rather than focusing on the theory'.* (Educationalist, Tanzania)

A physics curriculum expert commented.

*'Teachers should have the right attitude towards practical physics. They shouldn't wait till examination period before introducing the students to practical work. They should also sacrifice their time during the weekend to teach the students and should make use of the available equipment and in some cases improvise'.* (Educationalist, Nigeria)

A school principal also supported this view.



*'I partially agreed with the teachers saying that there is not enough time to engage students but you have to create the time. During my time in the classroom, I do create time during the weekend organizing extra lessons for students'. (Principal, Nigeria)*

Some of the participants believed that teachers tend to have the right attitude to teaching practical physics when they are supported and encouraged to give their best in carrying out their job. They suggested improved salaries and teaching conditions of physics teachers. A physics teacher said that motivation is very important.

*'Motivation is another factor, teachers are ready to give in their best when they are motivated. It could be intrinsic or extrinsic motivation i.e. giving awards to performing teachers will really encourage others. It could also be financial incentives for physics teachers due to the practical nature of the subject'. (Physics teacher, Nigeria)*

A School Principal also said the following.

*'Motivation on the part of the government and appreciating the teachers by improving their science allowance will go a long way in improving the quality of practical physics in school'. (Principal, Nigeria)*

Another school principal suggested giving scholarships for physics teachers to further their education and also called for improved salaries. He remarked:

*'There should be scholarships for teachers to further their education. Teachers are not happy when they look at the salaries of nurses and other professions. Absorbing part of teacher's children's fee will also motivate them'. (Principal, Ghana)*

A school principal also said that the bright students should be trained and supported to become teachers. According to the principal, sending the most able students to the university to become teachers will attract the best brain into the teaching profession.

*'We need to get some of our good students to become teachers by giving them incentives - maybe sending them to the university to become teachers. Attracting experts into the teaching profession through improved remuneration'. (Principal, South Africa)*

A physics teacher remarked:

*'Most physics teachers still plan to go (into) other fields due to their meagre salary but they will rather stay if their salary is at par with other professions. There is need to encourage the best brains into the teaching profession'. (Physics teacher, South Africa)*

According to a teacher trainer, science teachers and students should be appreciated by government and also they should give them preferential treatment over those who are not in science.

*'Government should appreciate the teachers and students of science to me. They should not put them on the same level to those who are not into science because science involve a lot of preparation. Science teachers should be appreciated in Africa but currently, they are being paid lower wages than other professions'.* (Lecturer, Tanzania)

A University lecturer who is also a teacher trainer remarked:

*'.....There should be proper monitoring and reward for science teachers. Our country should invest in science, technocrats should also take stand against the politicians who make policies that are not favorable to science teachers, and there should be adequate training for science teachers to upgrade their knowledge on the subject'.* (Lecturer, Ghana)

Many participants emphasized that there is need for improved teacher preparation through adequate and regular assessment and internship for practicing physics teachers. Physics teachers should be given the opportunity to attend seminars, conferences and workshops with a view to improving their teaching skills. There are many comments on the need for professional training for physics teachers. Here are a few chosen to reflect the range of opinions offered.

*'In my opinion, government should arrange at least two training sessions in a year for science teachers. This will enable them to acquire deeper understanding on how to teach the subject'.* (Physics teacher, Tanzania)

*'IoP should also endeavor to come at least twice in a year because teachers do complain that the time for the practical training is not much. For IoP to sustain their project in the future, I think they need to groom some local trainers or tutors who can carry out training for the physics teachers in the absence of foreign intervention'.* (Educationalist, Tanzania).

*'Government should organize workshops for physics teachers. With my experience, when we meet at workshops, you discover that most teachers have challenges in certain physics topics most especially on work, energy theorem and projectiles. So, I feel that if we have people who are well knowledgeable in this area to come and lecture us and give us practical demos in these topics, it will help us in the classroom and the learning of the learners'.* (Physics teacher, South Africa)

*'....There is need for regular in-service training. We set up a syllabus but not training for teachers on the use of the syllabus. Teachers should relate what they are teaching with the environment and not only the syllabus'.* (Educationalist, Ghana)

*'Government should try as much as possible to organize seminars and workshop for physics teachers. We thank God for the recent seminar, but we want it to be a continuous exercise so that physics teacher will be able to update their knowledge'. (Physics teacher, Nigeria)*

*'Firstly, there is need for in-service training for physics teachers for them to be able to perform well, most especially in area of practical work'. (Educationalist, Nigeria)*

*'.....Professionalizing our teaching, training of teachers periodically, integrating theory and practice in the most effective way and serious supervision (will help in improving the teaching and learning of practical physics)'. (Lecturer, South Africa)*

(iv) **Regional Collaboration.** A small minority (3 of 66) of the participants suggested collaboration between African countries. They said that Africa should operate as a single continent and not as different countries, coming together to have a focal point where their problems can be shared and they can have a continent specific solution. According to a senior physics educationalist his country should not operate in isolation. He remarked:

*'All countries that IoP is involved in should come and have a strategic planning session either in Accra, Uganda or in South Africa so that we all come together and share ideas because the challenges that we experience here in South Africa may easily be the challenges in other African countries. The African continent should have a common approach in terms of dealing with these challenges and I think IoP has actually created a good opportunity for the African continent to develop this. So, we have to move away from Africa operating as little Islands, and have a common focus in terms of taking this program forward' (Senior official, South Africa)*

A physics teacher offered similar views on the need for cooperation among science teachers across Africa. He commented as follows.

*'We need to cooperate with other scientists. Maybe, there should be a particular website where physics teacher can share ideas. Africa should unite and have a single syllabus whereby we can have the same materials and topics for all countries. I think this will help us a lot and also to have our own center where our problems can be solved together, because cooperation is very much important for African scientists rather than to work individually. ....Interacting with other physicists outside our country will help a lot'. (Physics teacher, Tanzania)*

(v) **Learning technologies.** Predominantly but not exclusively in South Africa, some participants (9 of 66) were aware of the ways in which technology could allow improvement in the teaching of practical physics. Mobile laboratories and software were suggested. A school principal opined that

having good teachers who know how to use software could help in improving the teaching of practical physics.

*'I think we need good quality teachers who know how to use the software because experiment can be simulated. But my physics teachers prefer the students to do hands-on rather than using the software'.* (Principal, South Africa)

A physics teacher also believed that the use of video and animation can help the students to learn more. The teacher offered this comment.

*'Using video and animation will go a long way in improving the quality of our student .....'* (Physics teacher, South Africa)

A senior official suggested that teachers can make use of the internet to download practical software. He offered this comment.

*'Educators themselves must be encouraged to use the internet where they can download practical software. If the school has got a computer center, they can take the learners there to perform a lot of demonstrations using the software'.* (Senior Official, South Africa)

According to him, prescribing experiments for teachers in the curriculum is not a good idea as he said that teachers must be at liberty to include additional activities over and above those prescribed.

A head of department in one of the high schools visited suggested that teachers need to realize the potential of the internet. He offered this comment.

*'Teachers need re-orientation from the old mentality and re-awakening. Having internet access at a reduced rate so that teachers will find it easy to pick information from the internet (will improve practical physics teaching - Editorial addition)'.* (Head of Department Ghana)

A physics teacher also offered this comment.

*'Government should provide laptop for students to expose them to the use of ICT in science'.* (Physics teacher, Ghana)

An alternative idea was supported by a head of department. He commented thus:

*'Have seen in some schools where they are provided with a mobile lab and I think it will do us good'.* (Head of Department Ghana)

## 6.2 Student Focus Groups and Interviews

### 6.2.1 Introduction

As already discussed in Chapter Four, 400 students participated in the focus group discussion and there were group interview sessions with the 80 group leaders of the 400 students who were asked to represent the consensus of the opinions and experiences of all the students. In spite of this instruction, the comments appear to include a mixture of consensus and personal views. The students were interviewed on their views on the current aims of the practical physics curriculum, their views on the present practice, assessment of their performance, factors influencing their performance and their opinions of the way practical physics teaching could be improved. The results will be structured to present comments relevant to the research questions using an ethnographic approach to define themes. These are used to quantify the overall emphasis of the comments.

### 6.2.2 What are the current aims of the practical physics curriculum in African schools?

The students were asked questions on their experiences in their practical physics lessons. From their replies, it was possible to draw out their understandings of the aims of practical physics. The main themes arising from the analysis were: (i) broader physics learning, (ii) practical specific learning, (iii) motivation and (iv) economic needs and priorities, four of the themes found in the comments made by the other groups of stakeholders. The students did not offer any comments that could be labelled clearly as opinions on exploration and discovery.

**Table 6.5:** Themes and numbers of students making comments on the aims of practical physics

<b>Country (Number of interviewees)</b>	<b>Ghana (20)</b>	<b>S. Africa (18)</b>	<b>Nigeria (16)</b>	<b>Tanzania (26)</b>	<b>Total (80)</b>
<b>Theme</b>					
<b>(i) Broader physics learning</b>	6	4	6	10	26
<b>(ii) Practical specific learning</b>	5	10	6	12	33
<b>(iii) Motivation</b>	3	2	3	11	19
<b>(iv) Economic need and priorities</b>	-	1	1	1	3

**(i) Broader Physics Learning.** The students commented that practical work improved their knowledge and that it gave them deeper understanding of the subject. Some of the students also believed that practical physics helped in reinforcing the theory that had been taught in class. One of the students said:

*‘I like studying practical physics because, when we are engaged in practical activities, it makes us to understand better. Also seeing is believing and whatever we practice will stick to our brain’.* (Student, Nigeria)

*‘In practical physics class, we carry out experiment to have a broader knowledge of the subject’.* (Student, Ghana)

*‘.....When you do practical physics, you understand more of the theory and also by doing it acquire more knowledge’.* (Student, Tanzania)

*‘I do like to study practical physics because they say practice makes perfect. When I learn the theory and also the practical, I understand more’.* (Student, Tanzania)

*‘.....I like studying practical physics because it improves my understanding of the subject’.* (Student, Nigeria)

*‘I do like practical physics because, by studying it, am able to apply what I have been taught in theory and put it into practice and also expand my knowledge of physics’.* (Student, Tanzania)

*‘I like studying practical physics because it makes me to understand physics better’.* (Student, South Africa)

*‘I like studying practical physics because it help us to understand the concepts been taught in the theory class’.* (Student, South Africa)

*‘I like to study practical physics because it will help my understanding of physics’.* (Student, Ghana)

*‘Yes, I like studying practical physics because we learn by doing so that we can understand better’.* (Student, Tanzania)

*‘.....It (practical) helps us to know the facts behind the theory’.* (Student, Ghana)

The students also believed that practical activities in physics helped them to make new discoveries and to verify the concepts and laws of physics. They argue that, by engaging in practical physics, they are able to see things in their real sense rather than just being told. An enthusiastic student remarked:

*‘.....we (students) get to see things practically than just hearing about it, for example, I won’t believe it if somebody tells me that if you put white light through a triangular prism, it produces seven different colors but when you take the prism and do it yourself, you get to see the different spectrum coming out’.* (Student, South Africa)

Other students made the following comments.

*‘It (practical) makes me to view physics as a reality.....when I do practical physics, I see things which are real. For example, when we do practical on simple harmonic motion, you realize why people put bells on their doors and you hear the sound banging across the door’.* (Student, Tanzania)

*‘We learn how different physicists did their things when they are still researching for different theory and laws. Like in upthrust, when you put a bucket inside water, it seems it now have a different weight’.* (Student, Tanzania)

*‘We experiment to verify whether the hypotheses we are finding are true or false’.* (Student, South Africa)

*‘We discover the facts behind the theory and get more information about physical science tasks’.* (Student, South Africa)

*‘We are trying to actually get a better foundation for the theory that we’ve learnt in class so that by doing the practical work, we get to see by ourselves and not just hearing’.* (Student, South Africa)

*‘We learn what we were taught in theory, learning how to observe, how to plot graph, making deductions from the graph such as intercept and slope etc’.* (Student, Nigeria)

*‘There are a lot of things we learn in physics practical, how to connect electricity and also learn how to prove different laws’.* (Student, Tanzania)

*‘We learn how to set up experiment and find out how true the concept we’ve learnt in theory’.* (Student, Ghana)

(ii) **Practical Specific Learning.** Many students mentioned skills development as one of the aims of practical work in physics. Skills such as designing experiment, handling and manipulation of equipment, innovation and creative thinking, observation and report writing were all mentioned. The following are examples of the comments made by the students.

*‘In practical (class), we learn how to use the instruments for doing a particular practical and how we can arrange them.....also, we learn how to prove different formula or constant (values) for example,*

*acceleration due to gravity is known to be 10 or 9.8 metres per second squared but through experiment, we can determine if it is true'. (Student, Tanzania)*

*'Well, when we are in practical physics class, first, we learnt how to handle the apparatus because some of us do not know how to handle some of this apparatus and also operating with different apparatus like the galvanometer and ammeter'. (Student, Tanzania)*

*'We learn what scientist are doing and also learn how to measure and take readings'. (Student, South Africa)*

*'We (students) learn how and why things work and also learn skill of measurement'. (Student, South Africa)*

Some comments referred to personal skills and attitudes, for example:

*'We (students) try to learn and acquire skills of observation and recording'. (Student, South Africa)*

*'Practical makes me to be a good observer and am also able to visualize what we've done in the syllabus and am also able to handle apparatus'. (Student, Nigeria)*

*'Practical helps me to develop confidence and give me more experience'. (Student, Tanzania)*

**(iii) Motivation.** The students said that practical work in physics helps them to relate physics to life activities. They enjoy practical physics because it is interesting and fun. They also enjoy the greater freedom they have during practical activities. They believed that their interest is stimulated by direct physical interaction with equipment and by what they can see and touch. The following are comments offered by the students.

*'In practical physics, we learn how to apply the theoretical knowledge that we gain in class and also find a way of applying physics to our daily life'. (Student, Tanzania)*

*'It (practical) make physics easier and when we learn by doing, it stay long in our memory.....It (practical) is also enjoyable and fun'. (Student, Tanzania)*

*'Yes, it (practical) is very interesting when you understand what you are doing'. (Student, Tanzania)*

*'Yes, as a science student we have to do practical physics because if we fail practical physics examination, then, we have failed physics'. (Student, Nigeria)*

*'Practical helps me to develop confidence and give me more experience'. (Student, Tanzania)*

*'Yes, I do like studying practical physics because an able to apply what am been taught in theory and put it into practice. It also expands my knowledge of physics'. (Student, Tanzania)*



*'Yes, because in practical physics class, we use our hands to manipulate equipment and this gives us confidence so that when we depart from school, we can apply what we have learnt'. (Student, Tanzania)*

*'Yes, I like studying practical physics because I find it very interesting'. (Student, Ghana)*

*'I do like studying practical physics because we get firsthand experience on what we have been taught by the teacher. Also, in the laboratory there is freedom and you do things yourself...I understand practical better than reading it from the textbook'. (Student, South Africa)*

Several students referred to the future value of physics in daily life. One student linked this explicitly to a career option.

*'I like physics practical more than any other science practical because physics is very interesting to me due to my future ambition of becoming an Electrical Engineer'. (Student, Nigeria)*

**(iv) Economic Needs and Priorities.** Only a few students were able to recognize the role of practical physics in addressing economic needs and priorities, though some saw it as a useful background skill. An enthusiastic student appreciated the market value of practical physics equipment and stated that:

*'It (practical) makes us to see things in different ways.....However, I will like to go into the production of equipment and make money from them as I learnt that they are expensive''. (Student, South Africa)*

Another student stated:

*'Physics is more useful in our society, it (practical) will help me build my own electric light and also help me in my environment'. (Student, Tanzania)*

*'I like physics practical than any other science practical because physics is very interesting to me due to my future ambition of becoming an Electrical Engineer'. (Student, Nigeria)*

### **6.2.3 What is the present status of practical physics education in African schools?**

The students offered many views on present practice in the teaching and learning of practical physics. Once again the comments have been gathered together into themes, as shown in Table 6.6. The themes are similar to those raised by the other stakeholders though the balance is somewhat different. In addition, the nature of the interview script has drawn out many comments on the attitudes of students.

**Table 6.6:** Themes and numbers of students making comments on present practice

Country (Number of interviewees)	Ghana (20)	S. Africa (18)	Nigeria (16)	Tanzania (26)	Total (80)
Theme					
(i) Student performance	20	18	16	26	80
(ii) Attitude of students	20	18	16	26	80
(iii) Resources and facilities	-	6	-	2	8
(iv) Time allocation	-	2	-	8	10
(v) Nature of practical activities	-	5	4	2	11

**(i) Student Performance.** The students expressed diverse views about their performance in practical physics and offered their opinions on problems influencing their performance. Some of the students said they are doing well in practical physics, i.e. they were able to set up experiments and analyze data gathered during the experiment, while some of the students said they were not doing well, i.e. they were unable to plot the graphs of experiments and had difficulty in handling the calculation aspects of practical work. The students offered these comments.

*‘We are trying our best but we are not that good in making connections and taking readings in electricity’.* (Student, Nigeria)

*‘We are doing well but still need to develop ourselves in some areas like plotting of graphs and in most cases setting up experiment. Most of us rely on others in the group’.* (Student, Nigeria)

*‘Practically, we are good mostly in the graphical aspect but our major problem is the calculation aspect which sometimes might not be from the topic’.* (Student, Nigeria)

*‘We are not good in arranging apparatus because we don’t have enough resources. We also need more help in the mathematical aspect’.* (Student, Tanzania)

*‘My mate and I are not actually doing well in practical due to the education system which focus more on the theory thereby making it hard for us to be good in practical’.* (Student, Tanzania)

*‘We don’t know anything as far as practical physics is concern’.* (Student, Ghana)

*‘I think we are doing well above average’.* (Student, Ghana)

*‘We are doing well in the little practical we’ve done’.* (Student, Ghana)

*'We are trying to do well but not done enough practical physics because of resources'. (Student, South Africa)*

*'We are trying our best but cannot really say we are doing well because when we are in the physics class, we sound knowledgeable but when we write exams we perform woefully. I think we are only good in recognizing equipment but always with low marks in exam. There is no assistance and less time from the teachers'. (Student, South Africa)*

**(ii) Attitudes of Students.** Many students described their level of interest in doing practical work in physics lessons. Several believed it gave them a better understanding of what they have learned in the theory class and that it had expanded their knowledge of physics. According to the students, they enjoy seeing things for themselves rather than being told and they enjoy the freedom of finding things out themselves. Some of the students also said that their prime interest in practical physics is for them to do well in their final physics examination while some said practical physics is very interesting and believed it will help them to build into their career in future. It must be noted that most of the comments quoted under "Motivation" in research question one are also relevant in this section on 'Attitude of students' - some have been repeated.

Here are a few of the comments made by the students.

*'I like studying practical physics because when we are engaged in practical activities, it makes us to understand better. Also seeing is believing and whatever we practice will stick to our brain'. (Student, Nigeria)*

*'Yes, I do like studying practical physics because am able to apply what am been taught in theory and put it into practice. It also expand my knowledge of physics'. (Student, Tanzania)*

*'Yes, because in practical physics class, we use our hands to manipulate equipment and this gives us confidence so that when we depart from school, we can apply what we have learnt'. (Student, Tanzania)*

*'Yes, I like studying practical physics because I find it very interesting'. (Student, Ghana)*

*'I do like studying practical physics because we get first-hand experience on what we have been taught by the teacher. Also, in the laboratory there is freedom and you do things yourself...I understand practical better than reading it from the textbook'. (Student, South Africa)*

*'Yes, as a science student we have to do practical physics because if we fail practical physics examination, then, we have fail physics'. (Student, Nigeria)*

*'Yes, because we get to see things practically than just hearing about it. For example, I won't believe it if somebody tell me that if you put white light through a triangular prism, it will produce seven different colors but when you take the prism and do it by yourself, you get to see different spectrum coming out'.* (Student, South Africa)

*'Yes, because you can observe and record even though they might be correct or incorrect answers. I feel so cool telling somebody about the momentum of a car or telling him/her that the car is changing velocity or acceleration and if he/she ask me how I do know and I will say that I did an experiment in that area'.* (Student, South Africa)

**(iii) Resources and Facilities.** A small minority of the students commented that the lack of resources and facilities was affecting their learning of practical physics. The students claimed that the inadequacy of practical physics equipment made it difficult for them to get engaged in practical physics regularly and sometimes led to their failure in physics. They offered the following comments.

*'.....There are no resources to do experiments which hinders us from making progress.....'.* (Student, South Africa)

*'.....Because the practical equipment are not enough, it means we don't do it regularly and not having enough competent experts'.* (Student, Tanzania)

*'We are trying to do well but not done enough practical physics because of resources'.* (Student, South Africa)

*'No resources to carry out practical activities'.* (Student, South Africa)

*'We are struggling to get equipment and this make us to fail physics sometimes'.* (Student, South Africa)

**(iv) Time Allocation.** A few of the students commented on the limited time available for practical activities which leads to their inability to perform well in practical physics. One of the students said the following.

*'We are not so competent because there are some practical that we are good at while we are not good in some other practical because we lack exposure. When we do a practical today, after a very long time we do another one. So, we are not used to do practical frequently and that is why we are not competent'.* (Student, Tanzania)

Other students provided similar comments.

*'We don't have enough practice.....we are only good in arranging apparatus and we need more help in the mathematical aspect'. (Student, Tanzania)*

*'We are not competent in doing practical because we do not regularly engage in practical activities'. (Student, Tanzania)*

*'..... We have not done enough practical'. (Student, Tanzania)*

**(v) Nature of the Practical Activities.** Some of the students commented on the type of instruction given to them in their practical physics classes.

*'I wouldn't say much about doing well or not .....we have a problem here, if you look at the mentality, they tell us here that just go home and figure it out. For some of us, it is just really tough to think of these concepts'. (Student, South Africa)*

There were comments on the current practice which entailed teachers giving them the result or readings of the experiment they have not performed or providing demonstrations. He commented as follows.

*'..... we should be able to do things individually and teachers not telling us or giving us things we want to find out already. Just give instruction and we do it ourselves and not the teacher doing it or giving you the recordings or readings of what had been done'. (Student, South Africa)*

*'The teacher introduces us to experiment and do the demonstration for us'. (Student, Nigeria)*

#### **6.2.4 What are the critical factors determining success and failure in delivery of the intended curriculum?**

There were a limited number of comments that related explicitly to the critical factors in determining success and failure. Students mentioned the lack of resources, lack of mathematical skills, and, more surprisingly, the belief that physics is only meant for an elite group. This demotivated some of the students from learning practical physics. The themes mentioned are listed in Table 6.7. Two are the same as those identified by the other stakeholders but 'lack of mathematical skills' was a preoccupation of the students.

**Table 6.7:** Themes and numbers of students making comments on critical factors

Country (Number of interviewees)	Ghana (20)	S. Africa (18)	Nigeria (16)	Tanzania (26)	Total (80)
Theme					
(i) Resources and facilities	-	8	-	2	10
(ii) Lack of mathematical skills	-	3	6	4	13
(iii) Attitude and motivation	-	4	-	-	4

**(i) Resources.** The students mentioned the inadequacy of resources and facilities as one of the major hindrances to effective learning of practical physics. Some student comments were as follows.

*‘Due to resources, we are not allow to do things for ourselves. I will like a situation where I am left alone to find things out by myself in the practical classes’.* (Student, South Africa)

*‘We are struggling to get equipment and this make us to fail physics sometime’.* (Student, South Africa)

*‘We are trying to do well but not done enough practical physics because of resources’.* (Student, South Africa)

*‘No resources to carry out practical activities....I will love a situation where everyone have their space and do things for themselves’.* (Student, South Africa)

*‘....Because the practical equipment are not enough, it means we don’t do it regularly and not having enough competent experts’.* (Student, Tanzania)

**(ii) Lack of Mathematical Skills.** A number of students mentioned that their lack of mathematical skills was affecting their performance in practical physics. Several claimed to enjoy practical physics but were afraid to solve the related mathematical questions. The students made the following comments.

*‘We are not good in arranging apparatus because we don’t have enough resources. We also need more help in the mathematical aspect’.* (Student, Tanzania)

*‘Practically, we are good mostly in the graphical aspect but our major problem is the calculation aspect which sometimes might not be from the topic’.* (Student, Nigeria)

*‘Doing exceptionally well but have problem with calculation’.* (Student, South Africa)

*'We are doing well in data collection but graph and calculation is a big challenge'. (Student, Tanzania)*

*'I like studying practical physics but am afraid of calculations'. (Student, Nigeria)*

**(iii) Attitude and Motivation.** A few comments related to the central importance of motivation and attitude. Some of the students said that their performance in practical physics was hinged on the belief that physics is only meant for certain groups of people and this makes them look down on themselves and think they cannot do well in practical physics. One example is as follows.

*'I'm not doing well, maybe am kind of lazy student or the impression that we got about physical science been very difficult for us. There is no resources to do experiment and you get home with the same mentality which hinders us from making progress. I think with more hard work and better attitude, I can do better' (Student, South Africa)*

This hints at an issue that is more explicit in the comment from another student at the same school.

*'We are trying our best but we have to be more dedicated and determined to achieve something at the end of the day for us to reach our full potential. We need motivation because we look down on ourselves as they keep saying that it is only the white people that can do this or that and we are not happy'. (Student, South Africa)*

#### **6.2.5 How can the teaching of practical physics in African schools be improved in the short and long run?**

Many of the student responses suggested reforms in practical physics teaching. As might be expected, the themes reflect the deficiencies they perceive, particularly in the availability of resources and time. Changes in attitude and motivation were also considered relevant.

**Table 6.8:** Themes and numbers of students making comments on improvement

<b>Country (Number of interviewees)</b>	<b>Ghana (20)</b>	<b>S. Africa (18)</b>	<b>Nigeria (16)</b>	<b>Tanzania (26)</b>	<b>Total (80)</b>
<b>Theme</b>					
<b>(i) Resources and facilities</b>	6	12	6	12	36
<b>(ii) Time allocation</b>	10	4	8	12	34
<b>(iii) Attitude and motivation</b>	4	2	2	2	10

**(i) Resources.** Many of the students asserted the need for additional resources. These included; adequate laboratory equipment, separate physics laboratories for practical activities, the

strengthening of teacher skills, and laboratory assistance support. The following were comments made by the students.

*'Physics practical must be perform in a conducive environment and there should be adequacy of materials without which we cannot perform in external examination'.* (Student, Nigeria)

*'We need a big laboratory and we should be able to do things individually and teachers not telling us or giving us things we want to find out already. Just give instruction and we do it ourselves and not the teacher doing it or giving you the recordings or readings of what had been done'.* (Student, South Africa)

*'I like the government to provide more equipment for us .....most of the equipment in our lab is old and faulty, they are not working well which sometime do frustrate us'.* (Student, Nigeria)

*'Will need a separate lab for physics practical because the lab we are using now is been shared with chemistry and biology'.* (Student, Nigeria)

*'Practical physics will be more interesting if we have modern equipment'.* (Student, Ghana)

*'.....We need some practical safety coat, more apparatus to do experiment regularly because we do practical once in a month'.* (Student, South Africa)

*'I will like it if the government can help providing more equipment our laboratory. We also want our teachers to encourage us to develop interest in the subject and must continue to teach us well'.* (Student, Nigeria)

*'We need laboratory textbook, lab coat etc. .... but now, we do practical once in a term and in some cases may be once in a year'.* (Student, South Africa)

*'Having adequate equipment and well-furnished laboratory'.* (Student, Nigeria)

The students also commented on the importance of having a teacher who is well equipped with practical skills to teach the practical aspects of the subject. Some suggested that teachers should change their teaching approaches to be more student centered.

*'.....giving us the best teacher who can impact the knowledge and also make provision for modern equipment'.* (Student, Nigeria)

*'We need a teacher who specializes on practical to be teaching us'.* (Student, Ghana)

*'Having somebody who is well equipped in physics practical who can be of great assistance for us'.* (Student, Tanzania)



*We need a good physics teacher, laboratory technician who can help out when conducting the experiment and guide us on various ways of conducting and correct us when we make mistakes’.*

(Student, Tanzania)

*‘The teacher should endeavor to carry the students along and should make sure they understand the concept been taught before leaving the class. Most of the time we do practical in groups and you will find out that not every student participated as many were on-lookers’.* (Student, Tanzania)

*‘Practical physics should be interesting and not that the teacher will leave us just on our own to be doing the practical when we don’t even understand. The teacher should be inside the class with us instead of roaming around. Also teacher should make sure that we understand the things we are doing and there should be adequate equipment to cater for the student population’.* (Student, Tanzania)

*‘My ideal practical physics session should involve teacher carrying the student along in the experiment by telling them what the function of those physics equipment and the kind of practical they are used to perform. Most of my colleagues don’t know the names of those equipment. Teacher should meet with the principal to provide the needed materials for most the experiment’.* (Student, Nigeria)

**(ii) Time Allocation.** Many students wanted more engagement in practical activities in physics and emphasized the need for more practical time in the school time table. Examples of such comments are as follows.

*‘I will like in our time table, there should be specific time allocated for practical physics so that if we are taught maybe electric current and before the next lesson, we should be introduce to the practical aspect..... the time for practical physics exams should be more than 2 hours’.* (Student, Nigeria)

*‘Providing adequate apparatus and creating more time for physics practical in the school time table’.* (Student, Nigeria)

*‘We need more practical on most of the topic in physical science. We only do practical once per term which is not really helping us to learn physics better’.* (Student, South Africa)

*‘More practical and doing practical physics every day’.* (Student, South Africa)

*‘Provision of apparatus and our teacher should also put more concentration on us to be doing practical regularly’.* (Student, Nigeria)

*‘There should be enough time to perform physics practical because it is interesting’.* (Student, Nigeria)

*'There should be more engagement between teachers and students and more practical work probably every week instead of once in a term'. (Student, South Africa)*

*'.....Practical physics session should be conducted frequently in order to expand our knowledge'. (Student, Tanzania)*

*'We should be having practical physics often with modern equipment'. (Student, Ghana)*

*'We need to carry out practical every time we have physics'. (Student, Ghana)*

*'.....Students should be given enough practice on the practical and should also be given enough time to practice them'. (Student, Tanzania)*

*'More time for practical activities and practical physics should be given some periods on the school time table.....' (Student, Tanzania)*

*'They should devote more time to practical physics and there are some practical that we ought to be doing but there are no apparatus to do them.....' (Student, Nigeria)*

*'We need more apparatus and frequent exposure to practical activities'. (Student, Tanzania)*

**(iii) Attitude and Motivation.** The students commented on changes in the attitudes of teachers that would assist their learning. Some of the opinions pointed to the need for teachers to be more inspirational. The students offered these comments.

*'I will like it if the government can help providing more equipment our laboratory. We also want our teachers to encourage us to develop interest in the subject and must continue to teach us well'. (Student, Nigeria)*

*'Teachers should let the students know the reality of doing practical physics'. (Student, Ghana)*

*'The teacher should endeavor to carry the students along and should make sure they understand the concept been taught before leaving the class.....Most of the time we do practical in groups and you will find out that not every student participated as many were on-lookers'. (Student, Tanzania)*

The quote listed under the third research question on critical factors points to a reform that some students saw as important.

*'We are trying our best but we have to be more dedicated and determined to achieve something at the end of the day for us to reach our full potential. We need motivation because we look down on ourselves as they keep saying that it is only the white people that can do this or that and we are not happy'. (Student, South Africa)*

## 6.3 Summary of Findings

This chapter provides qualitative data on the four research questions tackled in the thesis. It includes stakeholders' views on the aims of the practical physics curriculum. Dominant among these are the impact on broader physics learning with opinions on 'understanding of physics concepts' and 'reinforcing the theory'.

The stakeholders provided a large volume of comments on present practice and the critical factors affecting the teaching and learning of practical physics. They expressed diverse views on the student performance. Some argued that students achieve little while some were pleased with their performance. There were comments on students' inability to identify physics equipment and to set up experiments while some of the stakeholders asserted that students are able to do practical work but not the associated mathematics. Some participants in this study argued that the inadequacy of both human and material resources is one of the major hindrances to effective teaching and learning of practical physics. There were also assertions that there is lack of sufficient time for practical work due to the volume of work to be accomplished and the nature of the practical activities which they believed is confined to meeting examination requirement. The students commented on the lack of resources, their lack of mathematical skills and, more surprisingly, the belief that physics is only meant for elite groups.

There was a range of stakeholder opinions on ways of improving the teaching of practical physics. They suggested; building more laboratories with modern equipment, reducing the curriculum content, improving professional training for physics teachers, addressing the motivation of physics teachers, strengthening practical assessment and providing students with good background knowledge in physics at the elementary stage. There were also suggestions on regional collaboration among countries in Africa, having specialist practical physics teachers and teaching through the use of ICT. The students asserted the need for adequate laboratory equipment, separate physics laboratories for practical activities, strengthening of teacher skills and laboratory assistance support. They also emphasized the need for more practical time in the school timetable and changes in the attitudes of physics teachers that they believed would assist their learning. They want their teachers to be more inspirational.

In the next chapter, the comments made in this chapter will be triangulated with the data from the surveys and background data on the educational and social environments within which the schools operate.

## CHAPTER 7

### DISCUSSION

#### 7.1 Introduction

In this chapter, the findings from the study into the teaching and learning of practical physics in Africa's schools are discussed in relation to the research questions that were formulated to guide the study. The discussion is based on the quantitative and qualitative data that compared the responses of participants. Educationalists, senior officials from the ministries of education, physics lecturers from universities and colleges of education, high school principals, heads of department, physics teachers and students participated in the study. In addition, the demographic data in Chapter 3 provide a context for the stakeholder opinions and offers additional perspectives. These various data must be triangulated and informed by previous academic research and reports.

The discussion is organised by research questions which are discussed in turn. For convenience they are repeated below.

1. What are the current aims of the practical physics curriculum in African countries?
2. What is the present status of practical physics education in African schools?
3. What are the critical factors determining success and failure in delivery of the intended curriculum?
4. How can the teaching of practical physics in African schools be improved in the short and long run?

It must be noted that the quantity and quality of the information gathered is uneven. Inevitably, the data is shaped by issues of access to participants. There is under-representation of rural and remote regions and over-representation of 'centres of excellence' and exceptionally motivated staff. However, within such constraints, the surveys benefitted from high completion rates (100% in many cases) and good coverage of informed stakeholders.

In addition, the participants cannot be expected to provide all the information needed to answer the research questions fully. For example, the thesis contains a great deal of evidence on existing practice but stakeholder views on the range of potential interventions are limited by their lack of wide experience of effective practice.

For each research question there are findings that are predictable. These tend to dominate the data. However, there are also issues that have been raised by some participants that are less familiar – some may be of considerable importance to those interested in strengthening practical physics education in Africa.

It is reasonable to ask whether it is appropriate to answer the research questions for Africa as a whole. There are arguments why this is reasonable. Much of Sub-Saharan Africa is characterised by limited economic development, rapid population growth, limited teacher skills and numbers, and traditional social structures. These issues are relevant elsewhere, e.g. in South America. Given these similarities, it is not surprising that many common features relating to such issues are found in the survey data and interview responses.

However, SSA countries also have significant differences, not least in their political systems with, for example, strong centralisation in Ethiopia and Tanzania but greater scope for local initiative in Nigeria. Similarly educational policies and priorities differ across SSA. The discussion attempts to draw overall conclusions while recognising diversity.

A theme that will emerge in the discussion is that the factors influencing practical physics education are complex and are intimately connected. Later in the chapter, in the section addressing the factors that influence present practice, a system description is provided that attempts to show the linkages. The system description makes use of influence diagrams.

One of the aims of the thesis is to provide a description of the present position and an analysis of possible beneficial interventions. Several possibilities will be discussed. They will include the interventions that flow from discussion with stakeholders and those that represent major changes in approach, particularly those that harness new technologies. The system description can be used to guide and assess the likely success of such interventions

## **7.2 What are the current aims of the practical physics curriculum in African countries?**

In Chapter 2, five aims were adopted. These offered a succinct summary of previous academic analysis and were intended to help in structuring the investigation. They were;

- to develop skills in the design of experiments and investigations.
- to encourage skills of working together in a scientific context.
- to provide a context for the development of mathematical skills.

- to make new observations about the natural world.
- to encourage the development of skills in the design of instruments.

When asked to rank the above five aims that are framed in terms of advances in learning, the teachers ranked them as listed above with ‘to *develop skills in the design of experiments and investigations*’ given highest priority and ‘to *encourage the development of skills in the design of instruments*’ ranked last (Figure 5.3).

This ranking given by physics teachers is similar to the rankings found in previous literature. For example, Hodson (1990) identifies the main reasons given by teachers for using practical work in teaching, and “to teach laboratory skills” was second on the list, though it should be noted that Hodson was looking at science teaching in general and not physics in particular. Hofstein and Lunetta (2004) offer a similar list. Skills development was ranked third out of a possible five aims in their study. Woolnough and Alsop’s (1985) study looks at the aims but focusses on the types of practical activities/task undertaken by the students. Exercise was first on their list of practical activities which develop practical skills and techniques.

However, there is very little evidence that physics practical work in SSA addresses these five learning based aims. Instead practice is dominated by aims that are purely operational (gaining the qualification) or aims that address higher priority curriculum goals (e.g. informing and reinforcing theory).

The pragmatic focus on the qualification is reflected in the neglect of practical physics. Little time is devoted to it and the practical work that is offered is usually aimed at exam preparation. The limited perceived relevance of practical physics is evident from the responses of the teachers when asked to give a ranking of the requirement for achieving physics qualification. Their responses showed that *skills in practical physics* (the highest ranked learning aim) is ranked lowest of the four options as a prerequisite for gaining physics qualification. Instead, *understanding of physics content* is judged to be the most important qualification priority (Figure 5.4). This view is echoed by students who are exam focused and are seeking content knowledge and understanding.

The qualitative data gathering gave the stakeholders the opportunity to state what they think are the aims of practical physics teaching without the constraint of choosing from a list. Their responses, which are summarised in Table 6.1, included aims that could be found in the five listed aims but also presented other views. The dominant theme in the free comments was ‘broader physics learning’ with emphasis on ‘*understanding of physics concepts and reinforcing the theory*’. Practical specific learning, the next theme in their responses offered opinions on ‘*skills in designing, handling and*

*manipulation of experiment* as well as *making observations, report writing and creative thinking*'.

There was also comment on exploration and discovery with opinions on *making new discoveries and verifying facts and laws of physics*. These are broadly consistent with one or more of the five aims.

However, a significant proportion of stakeholders injected views on additional aims. They saw roles for practical physics in *sustaining and motivating the interest* of students and in contributing to *personal or wider economic needs and priorities*. It is worth noting that the aims that lie outside the chosen five were recognised by previous authors. For example Kerr (1964) included motivation (Table 2.1) as an aim but teachers did not rank it highly. Beatty & Woolnough's (1982) study also had motivation (Table 2.2) on their list of aims but, once again, teachers didn't rank it highly. From these views, it could be speculated that overt recognition of the potential for student motivation is more relevant in educational systems that are more challenged.

In the paragraphs below, the aims offered by the stakeholders are discussed more fully.

### **7.2.1 Broader Physics Learning**

The stakeholders interviewed in this study asserted that practical work improves factual knowledge and gives students a deeper understanding of the subject, and that practical activities also help in reinforcing the theory that is being taught in the class (Table 6.1). This view was supported by the students who claimed: that practical work helps them to understand physics; that they are able to learn well from practical work in physics (Figure 5.11); and that they enjoy practical because it helps them to understand the theory (Figure 5.12).

These claims align with the assertion by Wellington(1998) who grouped the reasons for doing practical work under three broad headings: cognitive, affective and skills, with the cognitive aims of '*improving pupil understanding*' and '*helps to confirm theory work*'. The stakeholders' assertions were also in line with Hodson (1990) who argued that practical work helps to '*enhance the learning of scientific knowledge*'. This view has been supported by other authors (Tamir, 1973; Bennett, 2003; Parkinson, 2004). One might ask why content understanding aims are not explicit in many published lists of the aims of practical physics. Is it because these aims are tacit but still important, or is it because the broader curriculum aims are not the priority for those able to devote considerable resources to delivering the curriculum? Is the SSA position different? Maybe teachers who cannot assume that the learning of content/understanding is adequately covered, see practical physics as an additional opportunity to cover the elements they consider most essential? At the very least, those intending to assist the development of practical physics in SSA should recognize that expectations may well differ from norms elsewhere.

### 7.2.2 Practical Specific Learning

The stakeholders' responses in the qualitative data revealed the belief that practical physics enhances instrumental skills, data analysis skills, and mathematical skills. Other skills such as designing of experiments, handling and manipulation of experiments, innovation and creative thinking, observation and report writing were also alluded to by the stakeholders (Table 6.1). The teachers' survey data also included the claims that practical physics helps to develop skills in the design of experiments and investigations (Figure 5.3). These assertions were supported by the students (Table 6.5). The students also claimed that practical work in physics helps them in developing skills such as designing of experiments, handling and manipulation of equipment, innovation, creative thinking, observation and report writing.

These assertions are in line with several authors (Muhasia et al, 2011; SCORE, 2008; Hofstein and Lunetta, 2004; Watson, 2000; Woolnough and Alsop, 1985; and Tamir 1973) who have argued that practical work enables the students to develop familiarity with apparatus, instrument and equipment, and that students also acquire manipulative skills and are able to develop expertise for reading scales etc. These claims do not appear to be contentious. Wellington (1998) also argued that practical work develops not only manipulative or manual dexterity skills, but also promotes higher-level transferable skills such as observation, measurement, prediction and inference. However, Wellington offered a cautionary comment on his claims by asserting that '*the evidence for the transferability of skills is limited*'.

Some stakeholders have argued that practical work should be thought of as fact finding-missions and that students should be able to discover as well as being told (Table 6.1). These roles appear in the lists developed in previous studies (Beatty and Woolnough, 1982; Kerr, 1963; Swain et al, 1999; Parkinson, 2004; Wellington, 2005; Ghebremariam, 2000) where practical work is said to be an integral part of the process of finding facts by investigation and arriving at principles. Although these views are offered by science/physics teachers, there is effectively no evidence that they are translated into practice – they can only be regarded as aspirational.

Overall, it is clear that stakeholders are aware of the importance of practical physics as an essential part of physics as a subject. They do not regard it as an adjunct that serves to elucidate theory but believe it has validity and value in its own right. However, for pragmatic reasons the subject balance is distorted. They respond to exam pressures and resource shortages.



### 7.2.3 Motivation

Many stakeholders have asserted that practical activities can help to arouse and sustain the interest of the students in physics. The direct sensory nature of experimentation was seen as relevant to motivation. This was linked to tangibility and relevance. Many of those interviewed asserted that practical work helped learners to relate what they have learnt in physics to what goes on in the natural and industrial environment (Table 6.1). By carrying out practical work, students gain insight and are more able to solve life problems.

Findings from the student survey corroborate the stakeholders' assertions about motivation. A large majority of the students across the four countries surveyed claimed that they enjoyed doing practical work - it is their favourite part of physics lessons. They also prefer the freedom they have during practical work compared to the theory sessions (Figure 5.11 and Figure 5.12). The responses from the focus group discussions with the students supports these assertions. The students claim that practical work in physics helps them to relate physics to life activities. They claim to enjoy practical physics because it is interesting and fun. They asserted that their interest is stimulated by direct physical interaction with equipment, by what they can see and touch (Table 6.5)

Similar findings were reported by Collins (2001), who argued that practical work creates motivation and interest for learning physics as it allows tacit knowledge of scientific phenomena to be gained. Millar (1998) has also argued that practical work should be viewed as an important means of allowing physics learners to reconcile and link the physical world with its physics description. Supporting this assertion is Barrow (1999) who argues that practical work is interesting and fun, providing pupils with the opportunity to work with materials that they may otherwise never come across. Findings from several other authors have also argued that practical work tends to motivate and stimulate student interest in science (Tamir, 1973; Kerr, 1963; Hodson, 1990; Watson, 2000; Parkinson, 2004; Bennett, 2003).

In contrast, Abraham (2009) has argued that practical work is ineffective in maintaining students' interest in science and does little to ensure that students continue to study the subject after it is a compulsory part of the curriculum. This was also supported by (Cleaves, 2005; SCORE, 2008, Wilson and Ward, 1997).

Overall, the evidence for the relevance of motivation in SSA practice is not convincing. The comments made by students and stakeholders tend to be very general and to lack the vivid anecdotes that would suggest real impact. Student groups who have little exposure to instrumentation and measurement cannot be reporting their direct experience and may just be

anticipating that novelty would be motivating. There is little evidence that students have grounded expectations that practical work will have employment relevance which has high priority in the thinking of SSA students.

It might be sensible to assume that the comments about motivation express aspirations rather than aims and to speculate that the subset of students with intellectual curiosity about science/physics are susceptible to being motivated for reasons that transcend the thinking of the broader population. But it is also an established fact that many students avoid the sciences because they appear to be abstract and difficult for the students to grasp.

#### **7.2.4 Economic Needs and Priorities**

In the qualitative analysis, some stakeholders related skills acquisition to the economic needs and priorities of the individual and society as a whole. They asserted that students can contribute to the development of a country if they acquire the necessary skills (Table 6.1). This was also supported by some students who were able to recognize the role of practical physics in addressing economic needs and priorities and saw it as a useful background skill (Table 6.5).

The economic imperative is included in the aims listed in the physics curriculum document of the countries involved in this study (CAPS, 2011; NERDC, 2009; CRDC, 2008; TSCE, 2009)

The primary aim of the practical physics activities in the Ghana physics curriculum document is to enable Ghanaian society to function effectively in a scientific and technological era, where many utilities require basic physics knowledge, skills and appropriate attitudes for operation (CRDC, 2008).

The South Africa Curriculum Assessment Policy Statement (CAPS, 2011) states that practical physics will prepare learners for future learning, specialist learning, employment citizenship, holistic development, socioeconomic development and environmental management. CAPS plays an increasing role in the lives of all South Africans because of its influence on scientific and technological development which is necessary for the country's economic growth and the social wellbeing of its people.

The Nigerian Education Research and Development Council (NERDC, 2009) has asserted that practical work in physics will enable the students to acquire essential scientific skills and attitudes as a preparation for the technological application of physics.

The Tanzania Certificate of Secondary Education (TCSE) description asserts that engaging students in practical work in physics will promote scientific and technological knowledge and skills in management, conservation and sustainable use of the environment (TSCE, 2009).

## 7.3 Policies and opinions across SSA

The discussion of aims so far has been framed in terms of the interview and survey data. An obvious question is whether there is consistency between such stakeholder views and the curriculum strategy documents that are intended to guide educational practice. Are stakeholders reflecting policy and do the policy documents themselves agree on the aims of the practical physics curriculum? The aims of teaching practical physics as stipulated in the strategic policy statements are set out in Table 7.1.

**Table 7.1:** The aims of the practical physics curriculum as indicated in national curriculum documents. Minor editing has been used to shorten some entries.

Country	Curriculum Aims
<b>Ghana</b>	<ul style="list-style-type: none"> <li>•To provide, through well designed studies of experimental and practical physics, a worthwhile hands-on educational experience to become well informed and productive citizens.</li> <li>•To enable the Ghanaian society function effectively in a scientific &amp; technological era, where many utilities require basic physics knowledge, skills &amp; appropriate attitudes for operations.</li> <li>•To recognize the usefulness, utilization &amp; limitations of scientific methods in all life's spheres.</li> <li>•To raise the awareness of inter-relationships between physics and industry, Information, and Communication Technology (ICT), Agriculture, Health and other daily experiences.</li> <li>•To develop in students, skills and attitudes that will enable them to practice science in the most efficient and cost effective way.</li> <li>•To develop in students desirable attitudes and values such as precision, honesty, objectivity, accuracy, perseverance, flexibility, curiosity and creativity.</li> <li>•To stimulate &amp; sustain interest in physics as a useful tool for the transformation of society.</li> </ul>
<b>South Africa</b>	<ul style="list-style-type: none"> <li>•To make learners aware of their environment and to equip learners with investigating skills relating to physical phenomena e.g. classifying, formulating models, hypothesizing, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem solving and reflective skills.</li> <li>•To promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; and understanding of the nature of science and its relationships to technology, society and the environment.</li> <li>•To prepare learners for future learning, specialist learning, employment citizenship, holistic development, socioeconomic development and environmental management.</li> </ul>
<b>Nigeria</b>	<ul style="list-style-type: none"> <li>•To provide basic literacy in physics for functional living in the society;</li> <li>•To acquire basic concepts and principles of physics as a preparation for further studies;</li> <li>•To acquire essential scientific skills and attitude as a preparation for technological application of physics; and</li> <li>•To stimulate and enhance creativity</li> </ul>
<b>Tanzania</b>	<ul style="list-style-type: none"> <li>•To understand the language of physics</li> <li>•To explain theories, laws and principles of physics</li> <li>•To understand the scientific method in solving problems</li> <li>•To promote scientific and technological knowledge and skills in management, conservation and sustainable use of the environment</li> </ul>

	<ul style="list-style-type: none"> <li>•To promote manipulative skills to manage various technological appliances</li> <li>•To promote self-study for self-advancement in new frontiers of physics</li> <li>•To appreciate the role of ICT in the process of learning</li> </ul>
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Although there are common strands in the aims identified by the four countries, the emphases are different and there are major differences between the aims set out and the practice that was observed.

Ghana provides aims that are fairly comprehensive though there is no explicit mention of the relevance to the acquisition of content knowledge and understanding. There is a significant disconnection between such a long and demanding list of aims and the allocation of time and material resource allowed for their delivery. There is no prioritisation.

The aims listed for South Africa address mainly practical specific roles and do not reflect the preoccupation with content/understanding that was observed. There is no clear recognition of the opportunity to motivate.

The Nigeria practical physics curriculum is rather different. It has an explicit emphasis on the contribution of practical physics to broader physics (content knowledge, and understanding etc.) which mirrors practice. The aims do not mention motivation, but, in a short list, space is found to include the promotion of creativity.

Tanzania too starts its list with broader curriculum aims. It is interesting that it emphasises direct manipulation skills which are of limited relevance to contemporary physics while recognising that practical physics might affect appreciation of the role of ICT in learning.

At the strategic level of curriculum policy documents, it is clear that SSA does not have a common view. This does not appear to be a matter of detailed drafting but concerns the identity of practical physics as having a value that is independent of the wider physics curriculum. Does it merely support physics or have important additional roles?

It is quite clear that the practice revealed in this study could not deliver the aims for any of the countries listed. The exam systems are based overwhelmingly on factual recall which militates against the higher order learning included in the national curriculum aims. In turn the exam priorities influence resource allocation, teaching priorities and student attitudes. Little attention is given to practical physics.

The five aims that were listed in Chapter 2 and used to frame this study are clearly insufficiently broad to encompass the aspirations of Sub-Saharan Africa. The following expanded list expresses the

aspirations that are revealed in this study. It is for governments to prioritise and to commit the resource required to translate these aspirations into lists of achievable aims.

- Understanding of physics concepts.
- Reinforcing the theory learnt in physics.
- Acquiring skills (e.g. designing experiments, performing observations, analysis and report writing).
- Exploring and discovering physics laws.
- Motivating students, especially in relation to environmental and employment opportunities.
- Nurturing the personal development and life skills of students.
- Contributing to national economic development.

#### **7.4 What is the present status of practical physics education in African schools?**

This section will address the second research question on the present status of practical physics education in African schools. It will include comment on; the prevalence and nature of practical physics experiences, the resources that are available, the attitudes of those involved, and the achievements of the students.

The overall picture is discouraging. Physics, as an individual subject or as part of an integrated science, is widely taught as a standard part of the compulsory curriculum. In addition there is reasonable enrolment as an optional subject though there is a significant gender imbalance. However, with the exception of trailblazing centres which are often dependent on expatriate personnel or external resources, practical physics, where taught at all, is almost completely limited to exam preparation and teacher demonstrations. This narrowness of purpose and method is in direct conflict with the professed importance of practical science/physics set out in national curriculum strategies.

Stakeholders expressed consistent views on the current practice in physics education in Africa. They asserted that most physics teachers only teach the theory and leave practical work until the examination period. The practical syllabus is not completed, thereby limiting the extent to which it

can achieve the purpose for which it was designed. Resources are either absent or, where present, are not put to use.

There is scepticism about the professional skills of teachers in relation to practical work. Although students welcome practical work, most gain few relevant skills. Most students find it difficult to set up experiments, take readings, plot graphs and make necessary deductions on their own. The problem is further aggravated where mathematical aspects of practical physics are involved.

These remarks are elaborated below. As the topic of the section is current practice, the direct views of those involved are of particular relevance and the section leans heavily on the qualitative data set out in the previous chapter.

#### **7.4.1 Nature of the Practical Activities**

This study shows that practical activities are essentially confined to meeting examination requirements. In the qualitative study, several stakeholders claimed that the priority is to train students to pass exams and that practical work in the physics curriculum is seen as a means to pass those exams. The exam focus is apparent in several ways. The extent to which practical activities are offered at all depends on the summative assessment policy in the country. Where practical work is separately assessed, scheduled time is provided though the time is often very limited. Where it is not assessed, there is very little offered. Stakeholders assert that physics teachers only include practical sessions during exam periods and that the scope is limited to what is supposed to be learned in practical physics (Table 6.2). The pragmatic dominance of exam preparation is also clear in the way practical sessions are designed.

In many cases, there is little recognition of the broader learning possibilities of practical physics. For example, some students claim that the current practice in their practical physics class entails teachers either giving them the results of experiments that the students have not performed or providing front-of-class demonstrations (Table 6.6). When considering possible approaches to teaching practical physics, the majority (> 60%) of the physics teachers asserted that students should follow predefined steps in carrying out experiments and that they should be focused on the importance of getting the accepted answer (Figure 5.7). These views are reflected by findings from the survey which revealed that teachers believe that the physics curriculum is focused on preparing students for higher education and that few students gain skills of independent thinking (Figure 5.6). Such opinions contrast with the views expressed in the student survey, where students claim to dislike following prescribed experimental procedures and watching the teacher doing the experiment (Figure 5.13).

These tendencies for the nature of practical work to be defined by assessment requirements and by pragmatic considerations of efficiency are unsurprising. The broad findings reflect observations made by Millar and Osborne (1998) who claimed that practical work that was conducted in accordance with the UK National Curriculum was mundane due to the assessment. Lazarowitz and Tamir (1994) found that students are usually required to follow a recipe in order to arrive at a predetermined conclusion and, as a consequence, the cognitive demand of the laboratory tends to be low. Kind and Tabe (2005) also opined that assessment criteria lead some teachers to focus primarily on meeting assessment requirements rather than using practical physics as a method of broadening the learning of science (including physics).

Hodson (1990) argued that this impoverished approach was very common. He suggested that theoretical arguments and research evidence have reinforced the view that practical work in school science, as presently organised, is largely unproductive and patently unable to justify the often extravagant claims made for it. It should be noted that this view was advanced as part of a dialogue about reforming practice and shifting the emphasis of practical work in order to foster inquiry skills in the UK. A report by the UK Office for Standards in Education (OFSTED, 2008) provided similar findings. The report stated that the nature of most practical work in current secondary schools was recipe-style activities or worksheets. These restrict the progression of student's inquiry skills and theoretical understanding of science due to the reliance on '*transmitting knowledge about science*' (OFSTED, 2008, p.35).

In summary, physics teachers in SSA focus on students passing the examinations and obtaining high grades and this is having a great influence on the way practical work is carried out in most schools in Africa. Teachers only give high regard to practical work if it helps students pass examinations irrespective of its contribution towards developing practical skills or otherwise. Curriculum and examination-oriented practice which is prevalent in African schools, limits the scope of inquiry based learning. In addition, the traditional and outdated experiments that are used give little opportunity for discovery or contemporary skills acquisition.

#### **7.4.2 Resources and Facilities**

The availability of materials and skilled staff for effective delivery of practical work in physics has been a long term and major concern in African schools. In this sub-section the issues of class sizes, staff availability and skills, and material resources will be discussed.

Demographic and development issues are of fundamental relevance in considering resources and facilities. Sub-Saharan Africa has a rapidly expanding population and ambitious national plans for the

education of its young people. School populations are expanding rapidly, demanding new buildings, equipment and staff, while most governments have very limited budgets. Inevitably, provision cannot match desirable standards.

More than two-thirds of the physics teachers interviewed in the qualitative study asserted that they have large class sizes and very little equipment. This view is consistent with the quantitative data (Figure 5.8). The students also assert that lack of adequate resources with large number of students sharing equipment influences their learning of practical physics (Figure 5.13). Large class sizes (classes above 40 students) were the norm in about 60% of schools visited during this study. The issue was particularly prominent in Tanzania. Class size is a major consideration when teachers make pragmatic decisions about how they are going to teach. It is extremely challenging for a teacher to organise a practical class when confronted with 40-60 students with limited access to resources. The difficulty is exacerbated by limited training and exam requirements that do not recognise the importance of practical physics. Large class sizes also make the assessment of practical activities in physics difficult for the teacher – it is challenging to diagnose weaknesses and provide feedback to a large number of individual students.

Several educationalists corroborated the claims of the physics teachers. They opined that practical work is not done well because physics is the subject with the most acute shortage of teachers and that, in some schools where there are qualified physics teachers, there is no equipment, thus making the teaching basically theoretical. They also claim that there is insufficient laboratory assistance to support the physics teachers (Table 6.2).

The problems of large class size and shortage of teachers are exacerbated by a skills deficit. Although, the majority of the teachers claim to have good knowledge of physics content, they also accept that they have limited knowledge and skill in teaching the practical aspect of physics (Figure 5.6). An obvious consequence is that teachers tend to only teach the theoretical part of physics to the neglect of the practical aspect. This eases classroom management issues and is a tactic that avoids dealing with their limited practical knowledge.

Lack of material resources increase the problems that teachers face. According to the teacher questionnaire responses, the overall view of the physics teachers is that resources are not adequate. Although the majority of teachers assert that they have a dedicated physics laboratory, there are major concerns about the adequacy and state of repair of the laboratory facilities (Figure 5.2 & Figure 5.8). A clear majority of the teachers claim that they do not have laboratory assistant support (Figure 5.2). Student data confirm the stakeholder's claims. The qualitative study data included strong claims from students that the inadequacy of practical physics equipment made it difficult for



them to engage with practical physics regularly and sometimes led to their failure in physics (Table 6.6).

Although the lack of resources is evident, several stakeholders have pointed to lack of use of the equipment that is available while others have suggested that the lack of skills in teaching practical physics leads to a failure to make use of what is available and to innovate in providing worthwhile practical learning experiences.

These overall findings are consistent with previous research (Lazarowitz and Tamir, 1994; Kasande, 2008). These studies indicate that large class sizes, lack of laboratory apparatus and equipment, lack of qualified, well-motivated and confident staff (teachers and technicians) have had and are still having a strong influence in the way science (including physics) is taught in schools. Researchers in Nigeria (Ajayi, 2007; Okebukola, 1997; Olaleye, 2002; Ogunleye, 1999) have argued that inadequacy of good instructional material, equipment and laboratory facilities in schools affect negatively the effective learning of physics in schools. Ango (1990) attributed the poor performance of students in physics in Africa to lack of qualified and experienced teachers, and availability or insufficiency of materials in the laboratories.

#### **7.4.3 Lack of Teaching Time for Practical Physics**

Closely linked to the previous discussion is the issue of the teaching time devoted to practical activities in physics. The clear evidence from this study is that physics teachers rarely create time for practical engagement by their students. Informal observations during the visits showed that there is limited time given for practical physics in most of the school timetables. Although, most of the physics curriculum statements for schools in Sub-Sahara African recommend that teachers should teach practical alongside the theory, there is little evidence that this is carried out in practice.

The teacher survey suggested that there is insufficient time to explain topics to the required depth (Figure 5.6). A major concern that emerged from the qualitative study was that there is a lack of sufficient time for practical work due to the volume of work to be accomplished and the nature of the school timetable (Table 6.2). The findings from the student survey corroborate the stakeholders' assertion (Figure 5.13). The student survey also revealed that the overall physics learning experience is passive with nearly 80% of the teaching time spent watching, listening, copying the teachers' notes and working from textbooks, with only 10% of the physics lesson devoted to group-based practical work (Figure 5.10). Some of the students made a similar claim in the qualitative study. They asserted that there is limited time available for practical activities which leads to their inability to perform well in practical physics (Table 6.6).

Lyons (2006) discussed these issues in an account of the factors influencing physics and chemistry enrolment in the UK. He asserted that science teachers (including physics) do not have time to do practical activities due to the overloaded curriculum which compels teachers to focus more on completing the syllabus than on the pedagogy of science teaching. Osborne and Collins (2001) also claim that the lack of teaching time coupled with an overloaded curriculum is the reason why teachers use transmissive pedagogies.

#### **7.4.4 Student Performance**

Overall, the evidence from this study is that students in Sub-Saharan Africa learn little from practical work in physics, partially because of lack of opportunity and partially because of the way that practical physics is organised in schools. However, the stakeholders from the four countries tended to have different views on the achievements of pupils,

Stakeholders from Ghana asserted that students hardly acquire any skills as the majority do not engage fully with practical work but just get the data for the experiment without taking part in the corresponding practical sessions (Table 6.2). They asserted further that students have little incentive to engage as they can learn, reproduce and use the theory and pass the course without engaging with practical work. This assertion was supported by Ghanaian physics students. They argued that they (students) '*don't know anything*' as far as practical physics is concerned (Table 6.6).

Stakeholders from Tanzania made a similar argument. They asserted that students lack skills in identifying practical physics equipment and have poor mathematics knowledge which leads to poor performance of the students in practical physics (Table 6.2). This assertion was not limited to high school students but extended to university students. Physics teachers in Tanzania also claimed that their students only did well in practical physics when given detailed instruction on what to do, but, even with this help, they were unable to apply mathematical knowledge within the physics practical context. Tanzanian physics students were in agreement with these assertions: they claimed to be doing badly in practical physics due to an education system which focuses more on the theory. Some of the students also argued that they are not good in identifying and arranging practical physics equipment and that they need more help in the mathematical aspect of practical physics (Table 6.6).

The criticisms of the education system seem to be well founded and identify an important general issue. The theory focus and the lack of priority given to practical physics is clear in that 90% of schools in Tanzania opt for the 'Alternative to Practical' option to fulfil the examination requirements.

The picture is different in Nigeria where stakeholders argue that students are performing well in the practical physics element of external examinations. However, it is suggested that they still face a lot of challenges in data analysis and the making of necessary deductions (Table 6.2). These assertions were supported by physics students in Nigeria. Some of the students claim that they find it difficult to set up experiments and to plot graphs and complete other aspects of analysis (Table 6.6).

The majority of South Africa stakeholders contributing to this study argued that students perform poorly in physical science in matriculation examinations and attribute this to the low level involvement of students in practical physics (Table 6.2). This view was supported by the students. They claimed to be able to appear knowledgeable in their practical physics classes but perform badly when they are in the exam situation (Table 6.6).

The weak performance of South African students in matriculation examinations is a concern. Anecdotal records gathered during the study visit to South Africa revealed that about 80% of township schools fail badly in physical science. This might be because students can pass through high school without any involvement in practical physics. Another issue that might account for this high level of failure is the fact that physics and chemistry are fused together into physical science in the South Africa context and the teachers may not be proficient in teaching both subjects.

It is worth noting that data from the student survey revealed that students least enjoy the analysis aspect of practical physics, involving calculation, graph plotting and reporting (Figure 5.13). However, the students' weaknesses in these areas might not be due to a lack of knowledge of mathematics itself but might be linked to limited experience in modelling, the analysis of a physical system by a mathematical model.

The stakeholders' assertions are in line with the literature. Hodson's findings on the reality of practical work are that most school experiments are dull and uninformative, and that most learners don't recognise their purpose (Hodson, 1990; Hodson, 1991). Hodson claims that practical work practised in many schools and countries is ill-conceived, confused, and unproductive and has not yet been successful in achieving the goals it is purported to achieve. Millar and Abraham (2009) also confirm the findings by stating that although students find practical work enjoyable, they learn little from it. They assert that, a few weeks after carrying out a practical task, most students recall only superficial details and are unable to say what they have learned. These studies were conducted within contexts that are different from those found in SSA and, in some cases, were focused on deeper learning but they serve to emphasise the limited success of achieving intended learning goals via practical physics.

### 7.4.5 Attitude of Teachers and Students

The attitudes of teachers and students towards practical physics are rather different. Overall, teachers are reluctant to engage in practical sessions but students claim to both enjoy and benefit from such experiences. Both positions are understandable.

Several stakeholders questioned the commitment of teachers to practical physics teaching. Educationalists cite a lack of the skills required to teach the practical aspects of physics due to deficiencies in the training teachers have received. The consequence of teachers not having been exposed to practical activities themselves is that they tend to only teach the theory and are afraid to deal with the practical curriculum (Table 6.2). The ramifications vary with country. In countries where practical work in physics is assessed (Ghana and Nigeria), practical work covering just one or two experiments is scheduled for the period just before the examination. In countries where there is no practical physics examination (South Africa and Tanzania), teachers display an even more negative attitude toward practical engagement and revert to teacher-centered practical activities or neglect practical work entirely.

The teacher survey corroborated the weak skills assertions made by the educationalists. There were claims that most (>80%) of the physics teachers have good knowledge of physics content but the majority (70%) believed that they had limited knowledge and skills in teaching practical work (Figure 5.6).

There is some evidence that large class sizes combined with traditional hierarchical attitudes affect preferred practical teaching styles. In the survey data, teachers show a preference for practical classes to be structured in closed and easily controllable ways (Figure 5.7). Perhaps a lack of teacher confidence contributes to such preferences.

Several stakeholders discussed whether teacher commitment was influenced by other factors, notably pay and status. They painted a picture of an overstretched workforce who have no incentive to show imagination or creativity in meeting the practical work challenge or even in undertaking the personal development that might improve their professional contribution.

Most of the students in this study showed a positive attitude towards practical work in physics. Most (88%) of the students claimed that practical physics gave them a better understanding of what they had learned in the theory class and that it had expanded their knowledge of physics (Figure 5.11). The students further claimed that they enjoyed seeing things for themselves rather than being told and that they enjoyed the freedom of finding things out themselves. Some of the students asserted that their prime interest in practical physics was success in their final physics examination while

some were less closed in their thinking and claimed that practical physics was very interesting and believed it would help them to build their career in the future (Table 6.6).

Faize (2011), in his research on the problems and prospects of science teaching in Pakistan, argues that some teachers are not competent in teaching through activity methods. Osborne and Simon (1996) and Mohanty (2004) came to similar conclusions in their research on science education program in secondary schools in New Delhi. The lack of teacher knowledge, skills and confidence restricts the amount of practical work that can be performed in Fiji high schools (Cook & Taylor, 1999). The findings of a study conducted by Nivalainen et al. (2010) also revealed that teachers' lack of competency in practical skill affects effective delivery of practical work in physics.

The present findings are also in line with Najade (2008) who asserted that teachers in Africa are '*carriers of weaknesses*' which include inadequate exposure to teaching practice, poor classroom management and control, shallow subject matter knowledge and lack of professionalism. Olarewaju (1986) and Nwagbo (1995) also assert that ignorance of the teachers in terms of practical skills and the neglect of appropriate teaching approaches by the teachers contribute heavily to the low performance of students in Africa

## **7.5 What are the critical factors determining success and failure in delivery of the intended curriculum?**

This section addresses the third research question. It will include comment on the resources and facilities available for practical physics engagement, the composition of the physics curriculum including the exams, the attitudes of teachers and their students toward the teaching and learning of practical physics, and aspects of the social and cultural environment within which learning is taking place. In many cases, the issues are closely linked but the discussion will attempt to draw together groups of factors into themes, as in previous chapters.

As with previous sections in this chapter, the discussion will be informed by the data acquired from the teachers, students and other national stakeholders as well as the demographic and other contextual information. The stakeholders have identified many directly experienced critical factors. However, lying behind such factors are other less directly acknowledged influences on the choices made by stakeholders. These factors link together to comprise a system that shapes the teaching and learning of practical physics. Such a system is set out in a multiple influence diagram that may help in considering the likely effectiveness of any intervention and in designing the intervention to avoid likely obstacles.

Within this discussion, the emphasis is on the level of success in delivering the planned outcomes. It might be argued that the planned outcomes are not appropriate. However, where articulated fully in national policy documents, they correspond broadly with international norms. The issue of revisiting the curriculum aims will be addressed in a later section.

### **7.5.1 Resources and Facilities**

This study has shown that the most widely recognised factor influencing the teaching and learning of practical physics is the availability of both human and material resources. Most of the schools in SSA suffer from the general shortage of qualified and dedicated physics teachers as well as a lack of laboratory technicians (Figure 5.8 and Table 6.3). The large majority of the schools visited did not have a laboratory technician to support the physics teachers. The majority of the sampled physics teachers were not physics specialists but had studied physics as part of a broader course in their University or Training College. In some of the schools visited a significant proportion of the teachers did not have a bachelor's degree level teaching qualification.

The shortage of physics teachers, general resource constraints, rapid growth in the school population, and the demand for physics have led to large class sizes. Classes of more than forty students are common. As already noted, a large majority of the physics teachers in the teacher survey assert that large class size is one of the most important obstacles to effective teaching of practical physics (Figure 5.8). The students agree and claim that the greatest obstacle to their enjoyment of practical physics is the large number of students sharing equipment during their practical physics lessons (Figure 5.13). Large classes make severe demands on the classroom management skills of the teachers.

There is abundant evidence of laboratory and equipment inadequacies. The majority of the physics teachers argued that their school did not have sufficient laboratory facilities and that there was a lack of relevant modern equipment and instruments for practical work (Figure 5.2 and Table 6.3). Some of the schools visited are without a dedicated physics laboratory (Figure 5.2). In most schools, a single laboratory was provided for all science courses. More than eighty percent of the sampled schools had insufficient laboratory equipment to cater for the large number of students taking physics as a separate subject. In many cases, there are problems in maintaining equipment and keeping it secure. Such problems are barriers to the provision of the required resources.

These material and staff resource deficiencies are clear indications that provision of resources for practical physics is not high on the priority list of those allocating resource even though curriculum

documents highlight the importance of practical physics. This lack of commitment is likely to influence the success of any initiative aimed at promoting practical physics.

It has been argued by some stakeholders that laboratory and equipment deficiencies can be overcome by skilled and enthusiastic teachers and there are examples that support this view. However, it seems highly optimistic to believe that this offers a solution for all schools, given the many challenges that teachers face.

The student survey and the focus group interviews with the students corroborate the resource assertions from the physics teachers (Figure 5.2 and Table 6.7).

These various resource findings are in line with other international studies (Thair & Treagust, 1999; Ranade, 2008; Kasanda, 2008). These authors found that low maintenance standards in laboratories, lack of equipment, large class size, shortage of science/physics teachers, and lack of laboratory assistance for experiments are existing constraints which hinder the teachers from using practical approaches in their classroom and lead teachers to overuse lecture methods in the teaching of science (including physics). Halai (2008) had similar findings, stating that the shortage of science/physics teachers creates extra workload for the teachers, which compels them to teach both a large number of classes and a large number of students in each class. He stated further that the excessive demands on teachers is a major factor in leading them to focus on covering the syllabus for examinations.

### **7.5.2 The Physics Curriculum**

The overloaded content of the physics curriculum has been described by stakeholders as one of the major obstacles to effective teaching and learning of practical work in physics. In most cases, physics teachers teach practical work to fulfill examination requirements and, in practice, they don't create time for hands-on activities with their students.

Several stakeholders have asserted that the physics curriculum is overloaded with too much content, thereby giving little opportunity for practical physics engagement with the students (Figure 5.8). Teachers in this study felt they had to teach didactically to get through the physics content (Table 6.3). The teaching-learning activities in the physics classroom render the students as onlookers because of the lack of student oriented activities which are aimed at enhancing meaningful learning. A majority (>80%) of the students in the quantitative study assert that most of the activities in the physics lessons are teacher oriented. They claim that a large percentage (90%) of their teaching time is devoted to teacher explanation, copying notes, working from textbooks with occasional teacher demonstrations. The students had very limited exposure to hands-on related activities (Figure 5.10).

Content overload is signaled by the concerns expressed by both the teachers and students about the lack of teaching time to engage in practical physics (Figure 5.8). The perceived lack of time to learn about and carry out practical activities was also evident in the student survey where the students claim to dislike the limited time for practical physics lessons (Figure 5.13). The qualitative study also supports these claims by both the teachers and the students. Some teachers assert that there is lack of sufficient time for practical work due to the volume of work to be accomplished and the nature of school timetable (Table 6.3).

Assessment of practical work in physics is another issue of major concern to stakeholders. The clear evidence from this study is that practical physics is not included in the summative national assessment (leading to a recognized qualification) in some countries and is only weakly recognized in others. Rather, the understanding of physics content is the main requirement for success (Figure 5.4).

There is very little evidence that practical physics is included in formative assessment. Osborne and Dillon (2010) stated that *'an assessment activity can help learning if it provides information to be used as feedback, by teachers, and by their pupils in assessing themselves and each other, to modify the teaching and learning activities in which they are engaged. Such assessment becomes formative assessment when evidence is actually used to adapt the teaching work to meet learning needs'*. The lack of a formative assessment role for practical physics activities should be seen as part of a wider picture involving over-stretched teachers and large classes. Effective formative assessment requires scarce teacher time that is not available.

The signal sent to teachers and students by the lack of assessment of practical physics is unambiguous. In a well-known remark Rowntree (1987) asserted that *'Assessment methods largely determine what and how students learn'*. In Sub-Saharan Africa the drivers for inclusion of practical physics activities in an overloaded curriculum by overworked teachers are very weak. Where such activities are included they are likely to be designed to deliver required competences, particularly knowledge of content and theory.

### **7.5.3 Attitude and Motivation**

This sub-section will discuss the attitudes and motivation of teachers and students. Relevant issues are lack of practical skills and professional development and student perceptions of the difficulty of physics and its relevance to them and their communities.



It is difficult to generalise accurately about teacher attitudes. Some stakeholders comment favorably on the commitment of teachers but they and others point to factors that are demotivating, notably level of remuneration, limited career prospects and lack of professional skills.

Several physics teachers complained that their remuneration is poor (Figure 5.8) and that there is little government interest in using familiar mechanisms such as special allowances to mitigate the inadequate pay. Some physics teachers claim that most teachers only continue to teach because there is no alternative employment. Some educationalists suggested that policy makers tend to have little understanding of science and, lacking empathy, they might not recognize or even acknowledge the need to address teacher motivation (Table 6.3). Such assertions were also made in the teacher survey. It is difficult to test the validity of these views but sympathy and action at senior and strategic levels is certainly a relevant factor in ensuring that practical physics teaching is supported appropriately.

The nature of the training received by physics teachers has been another issue of concern. Some educationalists argue that there is a cycle of incompetence. They assert that most of the physics teachers are not skillful in handling the practical aspects of physics because they were never exposed to practical work during their own training. In turn this was because the trainers themselves had little confidence and limited expertise. This skill gap helps to explain why teachers prioritize the theoretical part of physics (Table 6.3). This argument was supported by the teacher survey. The physics teachers claim to have a good knowledge of physics content but have very limited knowledge and skills in teaching practical work (Figure 5.6).

The lack of continuous professional training of teachers was among the issues raised by participants in this study (Table 6.3 and Figure 5.8). It is evident that physics teachers don't have the opportunity to attend seminars and training workshop to develop their skills in handling practical activities in physics. The study reveals a mutually reinforcing system in which there is little commitment to improvement at the level of the teachers and little opportunity for development provided by the authorities. Some educationalists further argue that, although governments are trying to change the curriculum, the teachers are still the same ones who passed through the old system and that they lack the skills to deliver the required changes.

The lack of developmental training for physics teachers is an issue of great concern in Sub-Saharan Africa. The various agencies responsible for curriculum development, clamor for a change in the curriculum to align with global best practices and to be able to meet the demand for science and technology in the 21<sup>st</sup> century but fail to assist the teachers to upgrade their knowledge for effective implementation of the new curriculum.

Student attitudes to practical physics are linked to their perception of physics as a whole. Some of the students see mathematics and physics as difficult subjects and this may reduce their commitment (Table 6.3 and Table 6.7).

In some of the countries visited in this study, some students appear to believe that physics is appropriate for certain groups of people, notably the privileged and white populations and, as a result of this view, students tended to develop a negative attitude towards physics and mathematics which in turn influences their performance in practical physics. This belief appears to relate to expected roles in later life.

The findings in this sub-section are in line with reservations expressed by Semela (2010) in his study on the factors influencing the choice of physics among Ethiopian university students. He noted that there is low enrolment in physics courses at all levels of education. He suggested that the reasons for include; inadequate lower level preparation, weak mathematics background, lack of job opportunities outside the teaching profession, inadequate teacher qualifications and teachers having poor pedagogical content knowledge.

SCORE (2008) reported that teacher inexperience and the lack of continuous professional development are barriers to practical work in science (including physics) among science teachers in the United Kingdom. However, it is worth noting that the UK science teachers didn't mention any lack of motivation or dissatisfaction about remuneration, in contrast to the findings of this study. Findings from previous studies (Asikainen and Hirvonen, 2010; Ishak & Mohamed, 2008; Kasanda, 2008; and Taylor and Dana, 2003) have also supported the findings in this study. They assert that teacher's pre-service and in-service training are not adequate thus leading to students' failure to learn practical physics. Thair and Treagust (1999) in their research on the importance of practical physics in Indonesian secondary schools asserted that the lack of teacher knowledge, skills and confidence has a great influence on the amount of practical work that can be performed by the students.

#### **7.5.4 Systems description of the factors affecting the teaching and learning of practical physics in Africa**

The previous discussion has been framed in terms of identifiable distinct factors but it has been clear that the factors are heavily interdependent. In developing the argument further it is necessary to move beyond separate themes and look more broadly at the system as a whole. This might help in seeking answers to important questions. Where can change in the system be nucleated most effectively? Which elements are hindering progress? How do the elements of the system influence each other?

The following are factors identified in this study that influence effective teaching and learning of practical physics in African schools.

- Practical physics equipment.
- Practical physics laboratory.
- Class size.
- Laboratory assistance support.
- Teacher skills.
- Teacher motivation/remuneration.
- The physics curriculum.
- Available teaching time.
- Student educational background.
- The nature of physics.
- Professional development.
- Assessment of practical physics.

The list is not exhaustive. These and other factors are heavily interdependent. So, for example, teacher skills are influenced by professional development opportunities and teacher motivation. One way of illustrating how these various influences interact is to prepare a multiple influence diagram showing relevant factors, how they influence each other and how they influence the central issue; the effectiveness of practical physics learning and teaching.

Figure 7.1 is such a diagram. The blobs in an influence diagram are the key structural ‘components’ of the system. The arrows represent the direction and strength of the influence. This diagram shows the factors that influence practical physics learning and teaching directly. These are represented by the arrows that end on the central node. Further towards the diagram’s periphery are the factors that underlie these direct influences.

In constructing an influence diagram, it is necessary to define the boundaries of the system being considered and, in this case, the boundary has been drawn widely to indicate that large scale political, financial and social structures are highly relevant.

The Open University website gives a vivid explanation of the purpose, elements, conventions and guidelines for constructing an influence diagram (The Open University, 2016). Influence diagrams identify the factors (structural features such as people and events) that have direct and indirect

influence on a system and its environment. Unlike a multiple cause diagram which traces change over time, influence diagrams identify factors with the capacity to influence at any particular point of time. Influence diagrams can be augmented to differentiate between strong and weak influences.

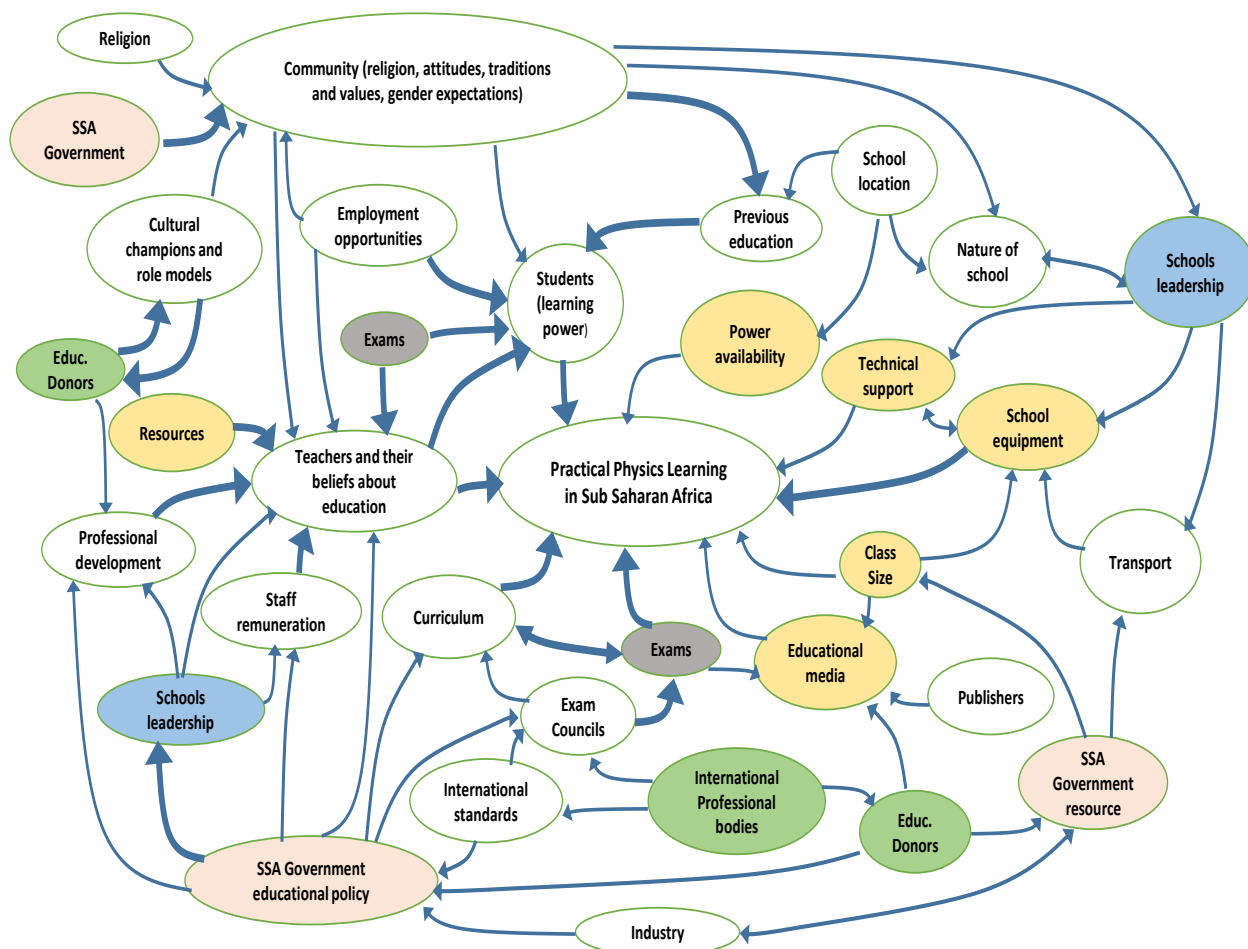
As described by the Open University, influence diagrams are used to:

- present an overview of areas of activity, groupings of people or other organizational features relevant to the situation or issue under consideration (the system of interest);
- express a broad view of how things are interrelated in the area under consideration;
- explore interrelationships, perhaps leading to re-grouping and re-definition of a system and its components.

An influence diagram showing the relationship between the factors influencing the teaching and learning of practical physics in Sub-Saharan Africa schools is shown in Figure 7.1. The influence diagram was prepared in consultation with some senior UK educationalists who are volunteer coordinator for the Institute of Physics (IoP) in Sub-Saharan Africa.

In the remainder of this section, some influences (factors) represented in the diagram will be considered in greater detail. These cases are chosen because of the relevance of the broader system in modulating their influence.

The influence diagram in Figure 7.1 consists of a number of blobs with different colors. The blobs with pervasive influences on practical physics teaching are: school leadership, exams, international professional bodies, educational donors and SSA government and resources. These titles are labelling blobs of different sizes and appear more than once on the diagram because of their capacity to have a great influence on other elements in the system. Also, the arrows in the diagram are of various thickness. The thicker arrows originate on those elements that have a strong influence while the thin arrows indicate weaker influence.



**Figure 7.1:** Influence diagram for Practical Physics Learning in SSA

## Resources and School Leadership

Figure 7.1 reveals the pervasive influence that school leadership has on the overall system. School leaders influence teachers in their beliefs, remuneration and professional development. They also influence the ethos of the school and its material resources. Of course, the school leaders themselves are influenced by the expectations of the local community and Government and by relevant educational policies.

The linkage between leadership and resource availability is influential. It was very obvious during study visits that school heads had great influence on how new resources were used by the science teachers. There were examples of boxes of unused equipment in some of the schools visited, in spite of teachers experiencing shortages. In most cases, the equipment was either locked up in the school laboratory or the school head's office to ensure that the equipment was not damaged and thus unavailable during the final examination. The equipment was only released to physics teachers when the students were preparing for their final practical physics examination. Understandably perhaps,

the school leadership had little confidence in school security and/or maintenance capabilities and prioritised the final examination purpose rather than the development of practical skills and critical thinking.

The school leadership also makes decisions about the technician support available to teachers. Even if equipment is nominally available to teachers, the general overload and large class sizes may make it difficult to use the equipment without laboratory technician support. Maintenance too becomes a major issue as it requires reporting of faults and systematic processes run by a dedicated individual. In SSA, few schools have effective maintenance processes and teachers who may already lack confidence are likely to be faced by the prospect of setting up an experiment using faulty equipment for a large class.

As already discussed, large class size is a major obstacle which affects not only student experiments but also demonstrations. During one study visit, the researcher had an opportunity to watch a practical session where the physics teacher was demonstrating the relationship between *pressure and area* to a large class (above 40 students). The students had to visit the front desk in turn to view the equipment briefly with many students not having an adequate opportunity to view the demonstration with obvious damage to their learning.

### **Curriculum and Exams**

As already described, the practical physics curriculum and the qualification assessment processes have direct and major influences on the teaching and learning of practical physics. However, it is helpful to unpick the curriculum examination linkage and look at the influences exerted on each of these elements.

Examination requirements are determined by examination bodies acting as agents of governments and it would be reasonable to assume there would be harmony between the curriculum and the examination. The written curriculum defines the aspirations of the curriculum designers and these aspirations are unlikely to be met unless the exams and the exam arrangements are consistent with the aims and cannot be tactically subverted. In general, in Sub-Saharan Africa these conditions are not met. There are many examples to support this assertion. In several countries the qualification assessment processes ignore practical work completely. In others, lack of confidence in the ability to run meaningful practical examinations have led to the use of stereotyped predictable experiments or 'alternatives to practical' where students are provided with pre-prepared data to analyse. Hard pressed teachers are teaching practical physics to meet examination requirements not minding whether the practical specific learning goals set out in the curriculum are being achieved or not. As a

result, students tend to pass their examination through rote learning without acquiring any useful professional skills.

The design of the curriculum is influenced by Government with inputs from those defining international standards and employers, as well as the national education community, notably the universities, and international donor bodies. Similar bodies influence exam design. It seems clear that these 'stakeholders' have been reluctant to exert the influence that they have on these core elements of practice. Perhaps, this is because the Millennium Goal aspirations of mass participation and equality in the primary sector have dominated educational planning. It may also be traced to the weak voice of science focused employers in most SSA countries.

In some of the countries visited in the study, assessment of practical activities for formative purposes is given very low priority. Teachers might decide not to teach the practical aspect of physics and may just give their students readings of experiments they have not performed. Interestingly, there is a mismatch between student preference and teacher practice. Students dislike following rigidly prescribed experiments and/or watching the teacher doing the experiment while their teachers believed that students should follow predefined steps in carrying out experiments and should focus on getting the accepted answer. Again, this indicates the tactical preoccupation of teachers focussed on content-led examinations.

### **Motivation and Employment Opportunity**

Employment opportunity influences the motivation of students and teachers strongly. Discussion with the students during the study visits revealed that few of the students are interested in pursuing physics at the tertiary level. In most cases, students don't really know the kind of professional jobs available to them as physics graduates. Many assume that physics graduates become physics educators who are not as well paid as other professionals in Sub-Saharan African. Some students in Nigeria and Ghana asked where they might work except as a school teacher and if they would earn more money if they studied engineering or medicine.

Of course, the students and teachers are embedded in their communities and are influenced by the expectations and attitudes of their communities. It is common for economically challenged communities to prioritise educational advancement into well paid and secure professions. The arguments for the economic potential of a physics qualification are not recognised. Although these arguments could be considered to relate to the broader subject of physics and its enrolment, they are particularly relevant in influencing attitudes to practical physics as students lack an employment related reason to gain professional skills – it is only the qualification that matters.

The students are not the only ones influenced by the lack of employment opportunity. Physics teachers argue that they are not adequately motivated either in term of remuneration or better working conditions, and that this is sometimes responsible for their lack of commitment to the teaching of practical physics. Some stakeholders interviewed in this study also asserted that teachers remain in teaching because there is no alternative and might leave if they got a better job offer (Table 6.3). The lack of attractiveness of the physics teacher role leads to a preponderance of less able or well prepared entrants to the profession.

### **Teachers, their Beliefs and Professional Development**

As we have seen, most teachers in this study claim to be confident in their content knowledge but admit to limited knowledge and skills in teaching practical work in physics (Figure 5.6). This is highly likely to influence student perceptions and may have a knock-on effect in reducing the number of students who enjoy the subject and want to pursue a career in physics.

Teacher skills are influenced by the opportunity to take part in Continuous Professional Training (CPD) which is relevant to their needs. Unfortunately, there is little evidence of focused CPD in the countries visited apart from special initiatives supported by international donors and expatriate teachers/lecturers. As already mentioned above, CPD is more likely to be focused on other priorities, particularly those in the primary sector. Building CPD capacity is an obvious need.

According to SSA educationalists the professional training the teachers received at tertiary level is inadequate, particularly in relation to practical skills (Table 6.2 and Table 6.3). The educationalists link this to the way practical physics is currently being taught in schools. Some physics teachers acknowledge this. They said they were not confident in handling practical activities because they had no training on the use of some of the equipment. Anecdotally, some of the teachers taking part in CPD events demonstrated little or no familiarity with very basic equipment and processes, e.g. timing using a stopwatch. The reaction to such CPD events indicates that at least some teachers yearn for opportunities to update their skills in practical physics but, unfortunately, such opportunities are not provided by the government and by school leadership. Limited CPD opportunity and take-up is heavily influenced by the absence of effective Government action.

### **Community Values and Attitudes**

Gender expectations, religion, traditions and social values all influence student learning power in Sub-Saharan Africa. Here, learning power is used to denote the *'psychological traits and skills that enable a person to engage effectively with a variety of learning challenges'*. It is a term adopted by



Claxton in guiding schools in the development of young people who are ready to learn (Claxton, 2002).

The attitude of the student is the dominant influence on their learning power. The belief of some students that physics is a very difficult subject, often coupled with a weak mathematics background shapes the attitude of the students to the teaching and learning of practical physics. Some of the stakeholders claim that students allow the fear of mathematics to become embedded, thus creating fear of hands-on practical activities in physics. A study by Spall et al., (2004) reported that students' liking for both physics and biology declined over the years. The decline in physics was said be more pronounced than biology and this was a result of students' perception of the increasing need for mathematics which increased the difficulty of physics.

Gender issues are heavily influenced by the community. Several educationalists contributing to this study expressed dismay about the present position and future prospect of girls studying physics beyond secondary level. They identified under-representation of female physics teachers in absolute numbers as well as their contributions to workshops and conferences as significant influences. There are very few women in the 'physics community' in Africa. There were growing concerns about the decline in the percentage of girls studying physics at university.

Several older studies suggest that a difference in the attitude of male and female students towards science (including physics) is a consequence of cultural socialization which offers girls considerably less opportunity to be involved with technological devices and the use of common instruments (Johnson, 1987 and Thomas, 1986). Babajide (2010) carried out a study into the attitude of students in science in Nigeria and asserted that the more positive attitude exhibited by boys to science (including physics) might be due to the acceptance of the myth that boys are better in science subjects than girls. He further stated that sciences such as physics and chemistry tend to be thought of as masculine in nature by education practitioners. Blickenstaff (2005) offered some possible reasons for the gender differences particularly in science/physics education. Among the issues she includes are the following:

1. lack of academic preparation for a science career for girls;
2. poor attitude toward science for girls and lack of positive experiences with science in childhood;
3. the absence of female scientist/engineer role models;
4. science curricula that are irrelevant to many girls;

5. the pedagogy of science classes favors male students;
6. a chilly climate that exists for girls;
7. cultural pressure on girls.

Although these issues overlap and are loosely described, they indicate the range of community influences on the motivation and learning power of female students. One area which might be worth further attention is the lack of female role models for physics students in Africa. In developed economies, student motivation is thought to have been heavily influenced by charismatic role models, e.g. astronauts, TV presenters etc. The 'geek' fashion of the last few years has correlated with encouraging levels of interest in physics.

However, it must be noted that student interest in practical physics for both sexes is also influenced by the broader social customs and beliefs of the society. The society decides the type of education that its citizens will receive. Taking a broad international view, the impact of physics should be recognized as including wider consciousness - socially, intellectually, politically, philosophically etc. However, in spite of these innumerable influence of physics on a society, one finds that there are many factors in particular societies that may hamper the growth and development of practical physics education. Seweje (2000) suggested that some societies are literate and others are illiterate where literacy involves familiarity and skill in an activity. A scientifically illiterate society cannot adequately comprehend the length and breadth of science (physics inclusive) and, therefore, such societies may fail to promote the growth and development of science. Seweje opined that superstition is inimical to scientific literacy and that science cannot thrive under such condition. In terms of the social condition of a society, Seweje said the level of poverty, tolerance etc. are bound to determine the extent to which science can grow in such a society. It is worth noting that some societies in Africa can still be regarded as scientifically illiterate where the teaching and learning of practical work in physics cannot thrive.

Cultural issues may also hinder the perceived desirability of a scientific education. For example, Islamic sects in the Northern part of Nigeria have been fighting against the introduction of western education for more than a decade. Interestingly, more than 200 female students were kidnapped in April 2014 when they were writing their practical physics examination in the North Eastern part of Nigeria. In such an environment, the obstacles to students studying practical physics are formidable even if they have a personal interest.

Apartheid (a political and social system in South Africa while it was under white minority rule) promoted the notion that only the white population can study science (including physics) although

the black population might be suited to the arts and humanities. The hangover from apartheid is still affecting the attitudes of students to practical physics in South Africa as some of the students in this study claim not to be good in the practical aspect of physics because of their fear of failure. There remains an erroneous conception that physics is only for the gifted and clever (often equated with the children of the white minority).

## **7.6 How can the teaching of practical physics in African schools be improved in the short and long run?**

This section discusses interventions that could improve practical physics teaching in African schools both in the short and long run. Many of these possible changes are based on the views of stakeholders. They have suggested that provision should be made for adequate physics equipment, qualified and dedicated teachers, and laboratory assistant support, and have advocated restructuring the physics curriculum, and developing the motivation and attitude of teachers. These possibilities will be discussed. However, there are some potential improvements that arise from experiences and data that are not available to stakeholders – these too are discussed.

The need for improvement has been widely recognised and there have been several initiatives that are relevant to the present discussion. Therefore, the section will start with a short description of recent and present initiatives from governments, as well as international professional bodies like the Institute of Physics (IoP) UK, Royal Society of Chemistry (RSC) and the Open University UK.

In an effort to improve the quality of science teaching in Tanzania, the government embarked on an initiative of building a science laboratory in each school in the country. In 2015, the Prime Minister (Mizenjo Pinda) ordered all district commissioners, council executive directors and education officers to ensure that, by the end of the year, construction of science laboratories in all ward secondary schools was accomplished. This initiative is controversial - some stakeholders see it as a step taken in the right direction while some educationalists see this idea as a wrong step. They have argued that government should have started by providing essential science/physics equipment which the teachers could just take to the class for demonstration purposes and that the equipment could be kept in the office pending the construction of a science/physics laboratory. Others argue that *'the journey of a thousand miles start with a step'* and, having completed the construction of laboratories, the distribution of physics equipment can follow. Having done this, there should be proper monitoring of physics teachers by the government or school leadership to see that teachers are making use of the physics equipment for the benefit of the students.

The Nigerian government has also been involved in in-service training of science/physics teacher but this has not been on a regular basis. Some state governments in Nigeria over the past four years have embarked on a campaign of one student to a lap-top. This was done with the intention of introducing the students to learning technologies. The state governments helped the students to download textbooks which might be useful. These textbooks could be used offline in the student's own leisure time. Unfortunately, most of the students abused the use of the lap-top by downloading contents (music, videos, games etc.) which might not help their learning. The distribution of lap-tops to students has had little recognized effect on their learning because there was no follow-up on part on the government to see how successful the intervention had been.

The Ghanaian government has intervened to improve the quality of science/physics teaching and learning in Ghana (Green, 2010). The report of this intervention *Monitoring of Science Resource Centre in Eastern Region in Ghana* indicated that about 16 schools in the eastern region were designated as Science Resource Centres (SRCs) and were fully equipped. Other satellite schools in the region could visit the SRCs to engage their students in practical physics or to borrow equipment for use during the practical examination period. Although the initiative met with some success, the report mentions some shortcomings of the program, particularly in relation to the failure of the satellite schools to continue to visit the SRC schools. The following very practical reasons were given in Green's report:

- The coach used for transport needed repair.
- The levy raised from the satellite school students to pay for the transport was being held by the satellite schools. Most head teachers considered it better in terms of science education to use this money to stock their own science departments.
- The time it took to transport students from the satellite school to the SRC schools was too long and resulted in a very much reduced time for teaching. Some of the satellite schools are forty kilometres or more from the SRC schools.
- There was confusion as to whether the satellite school teachers or the SRC teachers were responsible for the teaching in the SRC schools.
- The satellite students were sometimes distracted by unfamiliar surroundings in the SRC schools.
- The timetabling between the SRC schools and the satellite school clashed.

These problems illustrate how difficult it is to design improvement programs that are operationally effective. In terms of the influence diagram, the positive influence of improved access to laboratory resources is subverted by other resource restrictions and human attitudes.

The Ghanaian Government, through the Ministry of Education, has also been involved in the training and supervision of science/physics teachers in the field and has established a National Science Resource Centre (NSRC) in Accra which is well equipped with necessary equipment for practical engagement. This centre was established with the aim of training students and teachers in hands-on activities. The teachers were trained on how to use resources at the centre to carry out different experiments which they might initially find difficult due to their lack of exposure. However, the use of the centre is irregular and inconsistent. It is very difficult for most science/physics teachers in the remote areas to visit the capital (Accra) for such training and the availability of such equipment in their schools is not known.

The South African government has been trying to enhance the teaching and learning of practical physics within a context of adequate teacher motivation. However, even though the physics teachers are generally motivated in terms of pay, they don't have the necessary facilities to engage the students in hands-on activities. Most of the township schools are without a science/physics laboratory. The approach has been to establish trail blazing centres (in Soweto and Cape Town) which are designed specifically for science students and supervised by an educationalist. The centres were established to tackle the problems being faced by students at high school level where most students pass out without exposure to practical activities. The main problem with these centres is that they cannot meet demand. Large class sizes (up to about 1000 science students) have made it difficult to engage all the students in practical activities due to equipment limitations. The South African government has started an initiative to improve the quality of physical science teaching by motivating educationalists in tertiary institutions to contribute to rural community development. Such contributions have led to individual educationalists organising teaching of physical science in rural secondary schools.

In addition to these locally led interventions, various international bodies have been engaging teachers and students in Africa with the teaching of physics. Notable among these bodies are the Institute of Physics in the United Kingdom and the UK Open University through the OpenScience Laboratory (OSL).

The Institute of Physics (IoP) embarked on the promotion of practical physics teaching in Sub-Saharan Africa more than a decade ago (IoP, 2012). The prime mechanism is the training of teachers at extended workshops led by experienced UK volunteers. These have taken place in ten African

countries. The IoP has aimed to enhance teachers' subject knowledge, to give them the practical skills necessary to run experimental classes and to show students the application of physics and the benefits of a physics education. Teachers are encouraged to use simple practical experiences in their classrooms to enhance the learning of the students. They stress that the teaching approaches they advocate could also be used in other science subjects. The IoP has also provided ICT and experimental equipment and has set up local resource centres that are available to communities within the broad surrounding area. They train local craftsmen to build experimental equipment and to manage the resources centres, thus facilitating self-sustainability and enhancing employment. The Institute of Physics (IoP) has established training centres in most of the countries where the UK volunteers are active.

Stakeholders in Sub-Saharan Africa have welcomed the IoP intervention and believe that the IoP presence had been of help to the physics teachers and students (IoP, 2012). The teachers enjoyed the experience and learned a great deal in a short time. The most important benefit of the IoP intervention was that the initiative demonstrated that meaningful professional development was possible without enormous investment. However, some stakeholders have opined that the training time is very limited and that there is a need for the IoP to groom local trainers or tutors who can carry out training for the physics teachers in the absence of foreign interventions. Although the IoP sought to engage with local leadership and, in many cases, enjoyed the support of Ministries, there is a lack of evidence of systemic take up. Governments and local leaders have not groomed local trainers or provided the resources needed for wider implementation. It is a reasonable speculation that leadership from the government and head teachers could still allow successful cascading but the influence of examination policy would still be problematic.

The OpenScience Laboratory is an innovative means of providing authentic practical science/physics education 'on screen', through remote observations and manipulation or control of experiments via the internet (Braithwaite-private communication). The software is designed as a 'hands-on' approach to practical work with an emphasis on exposing students to genuine data and inquiry. Users can work via the OSL's virtual laboratory interface to manipulate apparatus, take readings from instruments and generate their own real data that they can then analyse and evaluate. The platform doesn't simulate science/physics but deals with real data. The OSL makes authentic, practical science education possible in low-resourced areas, where equipment is rarely available (Open Pi Lab, 2016)

The OpenScience Laboratory approach can support secondary educators where access to well-equipped laboratories is a challenge. In 2016, this idea was taken to 10 schools in Kenya with a total

student population of 6000 pupils and to 500 teachers. The Open  $\pi$  lab, as it was termed, was used in the training of science teachers in Kenyan schools with the potential to provide practical science activities on-screen but off-line. Asynchronous and synchronous links facilitated deeper learning. Alongside effective mediation and training, it was believed that the resources had potential to make a significant impact in the context of Africa (Braithwaite-private communication). Plans are underway to take the scheme to more countries in Sub-Saharan Africa. A limitation of this scheme is that the Open  $\pi$  Lab is closely linked to higher education learning and efforts must be made to link most of the experiments with the secondary school science/physics curriculum.

Having discussed recent and current interventions, the next section will continue with the views of stakeholders on the way forward. The discussion is structured into broad themes.

### **7.6.1 Resources and Facilities**

Adequate resources (both human and material) are vital for effective delivery of practical physics in Sub-Saharan African schools. The availability of practical physics equipment is a prerequisite for improvement and will go a long way in influencing the present practice. The teacher survey reveals a desire for modern physics equipment with improved, and higher quality laboratory space. Some of the physics teachers suggested the building of separate physics laboratories. Some of the schools visited in this study use a single laboratory for all the science subjects while some don't even have a shared laboratory. There were also suggestions for improved supply of qualified and dedicated physics teachers as well as laboratory technicians to support the physics teachers.

The stakeholders called for reductions in class sizes which will enhance classroom management (Figure 5.9). The qualitative data also suggested the employment of separate physics teachers for practical work and adequate funding for science/physics education (Table 6.4). However, the possibility of a separate physics teacher for practical work might not be realistic in that most SSA governments are operating on a limited budget for education.

Perversely, it may be that resource restrictions are exacerbated by a wish to ensure equality of opportunity. The conflict between progress within limited resources and equity is worth debating. Sub-Saharan Africa Governments could develop better provision in stages, with access centred initially on areas of greatest employment need and potential, i.e. tailor educational provision to the local economy. This approach is found to varying extents in some developed countries, notably in Asia

These findings about the impact of resource constraints are in line with previous research. Guzman (2000) cited in Cossa (2007) argue that curriculum materials such as laboratory manuals, worksheets

and textbooks that includes exercises determine to a large extent the opportunities to learn. In a related study in Australia, Goodrum et al, (2001) argue that quality science/physics teaching is supported by excellent facilities, equipment, and curriculum resources including instructional technologies. They also note the relevance of manageable class size. Several authors argue that adequate supply of materials makes teaching more convenient and more effective. It increases the amount of student experimental work and enables teachers to broaden the science/physics curriculum. It also improves the correlation between the laboratory based resource and experiences and the achievement of students (Lazarowitz & Tamir 1994; Lunetta, 1998).

Taking a critical look at these suggestions raised by both the physics teachers and other stakeholders, one might ask if provision of physics equipment and laboratory assistance support are a complete panacea for effective teaching of practical physics. It is highly likely that adequate resources are necessary but not sufficient. The equipment might be readily available but are not used by the teachers because they lack the skills to teach practical work or because they do not prioritise such teaching methods. Perhaps they and school leaders do not prioritise practical science as it does not contribute to meeting their most important indicators of success, i.e. exam scores. Perhaps students see no point in engaging if there is no linkage to jobs. Perhaps girls will be last in the queue to use the newly available resources because their expectations and the expectations of their family are directed elsewhere.

### **7.6.2 The Physics Curriculum**

Physics curriculum documents are intended to dictate what is to be taught and how it must be taught. As already stated in an earlier section, the student experience of the physics curricula in Sub-Saharan African countries is inadequate to meet the intended goals for practical physics. Both curriculum design and delivery contribute to that inadequacy.

The teacher survey suggests that there should be review and modification to the existing physics curriculum. They claim that a reduction in the content of the physics curriculum will create more room for hands-on activities (Figure 5.9). Complementing the suggestion made by their teachers, the students suggest a more practical oriented syllabus, more time for practical lessons and introduction of project work, field trips etc. They believe such changes would go a long way towards improving student understanding of practical physics (Figure 5.14).

Would such reforms be effective? Given the challenges faced by teachers, a reduction in physics curriculum content would only be effective in stimulating more practical activities if linked to exam reform. This is recognised by several stakeholders who have claimed that formal assessment of



practical physics would be required to propel the teachers to engage the students in more hands-on activities. This is true generally but is particularly relevant in countries where assessment of practical physics doesn't form part of the final examination. Some educationalists suggest further that testing of practical work should be continuous, i.e. during and after each practical activity which should be embedded throughout the course. Teachers should not wait till the learners are in their final year or final months before assessment is carried out (Table 6.4). Such embedding would offer opportunity for feedback and would reinforce the connection between theory and experiment but would impose greater demands on the teachers and would require additional staff resource. It is likely that reform of this type would require phased introduction with evaluation of success as the reform proceeds.

The reservations about overload are in line with findings from Millar and Osborne (1998) who argued that the science/physics curriculum should be relevant to the needs of students and their environment and that it should contain less subject matter content and encourage in-depth learning of a smaller range of topics in order that the learners can develop positive attitudes and rational thinking processes with consequent improvement in scientific literacy. Such thinking is common in many countries.

The reform suggested by Millar and Osborne might be of value in SSA countries. There is a possibility of curriculum reorientation with emphasis on meeting local employment needs, e.g. more electronics, technically oriented activities and employability skills. Although reform must acknowledge international standards for physics qualifications, there is no reason why SSA could not engage with international educationalists to catalyse reforms that meet the needs of its citizens better than curricula that have been designed for other countries and contexts.

Some of the physics teachers and other stakeholders advocate that teaching of practical physics should begin in the elementary schools so that the students will have a solid background knowledge to build on when they get to the secondary schools. Such proposals are not realistic. At a fundamental level, physics learning is hierarchical and should take place at the appropriate stages of human development. The concept rich nature of physics with heavy reliance on abstraction is unlikely to be accessible to children who are still concrete in their thinking. It would be wrong to teach the physics content that is designed for high school students in lower level classes.

### **7.6.3 Attitude and Motivation**

The motivations and aspirations of teachers and students determine their attitudes and dispositions to the teaching and learning of practical work in physics. The issues of pay and status are important to teachers – they influence teacher behaviour, for example poor pay can lead to reluctance to

contribute beyond the contractual minimum, as well as encouraging moonlighting and the adoption of short cuts that allow targets to be met for minimum effort. In Sub-Saharan Africa in general, teachers believe that they are underpaid and have poor working conditions. They believe that they are not treated on a par with their colleagues in other professions. They believe that this discourages the most able from entering the teaching profession. Instead the best qualified currently opt for careers that have better pay.

Poor teacher pay and working conditions are linked to limited government budgets and the rapidly escalating numbers of teachers needed to cope with demographic changes. It is worth noting that, in many SSA countries, the education budget matches international norms as a percentage but governments suffer from weak tax revenues and as a result of this, fixing the poor pay problem for teachers will be a hard task.

Some educationalists suggest that teachers must not be used as ‘serving paper’ but should be well remunerated and encouraged (Table 6.4). They believe that teachers are nation builders and should be treated with the same level of respect as is found in more developed countries. It is felt that, when teachers have good motivation (both extrinsic and intrinsic), the career might attract better teachers and turnover might fall. The incidence of second jobs might be reduced. However, there would still be problems without other reforms of exams, material resources, teacher skills etc.

Apart from improved pay for teachers, there are other possible mechanisms for enhancing status. Examples include; national teaching awards and prizes, televised school practical science competitions, science exhibitions and links with universities. These reward mechanisms have been successful in developed countries e.g. United Kingdom and Finland. They require very limited budgets and can involve both teachers and students.

The importance of improving Continuous Professional Development (CPD) for physics teachers cannot be over emphasised. Teachers’ lack of confidence in handling practical work in physics is a professional failing and failure to address this will preclude the possibility of significant systemic change. In this study, stakeholders assert the need for professional training to nurture practical skills in physics teachers. This view was also echoed by the physics teachers. They believe that regular in-service training will increase their confidence in handling practical activities (Table 6.4).

Other authors have argued that *“long term and continuous professional development aimed at enhancing science/physics teacher’s subject knowledge and their pedagogical content knowledge can help teachers to develop higher levels of pedagogical content and subject knowledge, skills and confidence to construct effective learning environments that include substantive and meaningful*

*science/physics laboratory experiences*” (Gess-Newsome, 1999; Shulman, 1986). Hofstein and Lunetta (2003) also suggested appropriate long term professional development as one of the important ways to help teachers develop professional understandings, beliefs, roles and behaviours. Kennedy (1998) also argues that, when teachers undergo learning experiences that engage them in meaningful inquiry, they can become more effective in involving their own students in similar inquiry experiences.

High quality CPD can provide a status boost and, if separately financed and run out of normal teaching time, can boost the pay of teachers. Teachers can gain extra qualifications and can derive satisfaction from their new professional skills and their ability to enhance the experience and performance of their students. As with other professions regular CPD could be a requirement for ongoing license to practice. However, there are issues concerning the creation of an effective CPD program. Many SSA countries don’t have enough in-house expertise and, so, cascade processes might be difficult to initiate. The teachers themselves are over-committed and freeing time to take part in CPD is difficult. As always more resources would be needed to make CPD an attractive option for school leaders and teachers.

#### **7.6.4 Regional Collaboration**

A number of stakeholders have suggested that cooperation amongst African countries could go a long way towards strengthening teaching and learning of practical physics across Sub-Saharan Africa. While acknowledging and respecting interventions from International bodies (IoP, OU, RSC etc.) these educationalists suggests that African countries could and should come together and have a focus point for action. The study suggests the need for countries in Africa to first identify the challenges and adopt a common approach or continental solution. The harmonization of the physics curriculum among African countries is seen as an important goal.

A good omen for regional development is the evidence of long term success of such collaboration in West Africa where the West African Examinations Council has operated for sixty years. Its vision is *‘to be a world-class examining body, adding value to the educational goals of its stakeholders’*. However, if regional collaboration is going to work in Africa, there would be a need to establish that aspirations are genuinely shared. This is necessary because ownership of educational processes is a sensitive issue and strong drivers would be needed to overcome the inevitable barriers. However, it might be possible for countries to reform the physics curriculum substantially by working regionally and taking ownership of an African model of physics education. This might appeal to governments seeking to create social structures that do not echo colonial pasts.

There were also suggestions for the design of a website where physics teachers can share ideas. Those making this suggestion opined that interacting with other physics teachers across the continent would help improve the teaching of participants. The record of previous initiatives of this type is patchy with meaningful engagement often limited to a zealous minority. It is likely that strong incentives to participate would be needed to encourage teachers to join and use the forum.

Hofstein and Lunetta (2003) support the value of collaboration. They suggest the importance of providing support for teachers (including time and opportunities) to collaborate with colleague in the science/physics education community so as to understand, develop and teach in ways that are consistent with contemporary professional standards.

### **7.6.5 Learning Technologies**

The use of interactive computer-based experiments and observations in which students work with virtual rather than physical entities is seen as one approach for enhancing the teaching and learning of practical work in physics. The interest in adopting such approaches is worldwide and it is encouraging to note that some of the stakeholders in this study recognise the potential impact of learning technologies.

Initiatives of this sort have several potential advantages. Resource availability dominates stakeholder concerns as they discuss the factors that determine the teaching of practical physics. The use of learning technologies could help in solving some of the resource issues by reducing cost, easing the maintenance burden, and enhancing access to more sophisticated experiments. A technologically advanced interface could help to motivate teachers and students and provide a more contemporary image of practical physics. Workplace skills could be taught. African universities could design and/or adapt the necessary software. In addition, such initiatives are likely to attract donor support and meaningful international collaboration. Finally Sub-Saharan Africa has a strong track record in using new technologies such as mobile phones to transform the way society operates – there is a readiness to change.

The use of technology in learning has been steadily increasing in the economically developed countries while its use is still very limited in African schools. The teacher survey surfaced suggestions centred on the use of mobile laboratories and other e-learning techniques. The student survey also suggested the use of computer based instruction and supported the introduction of mobile laboratories as opined by the physics teachers. Other stakeholders corroborated the views from the student and teacher survey. They asserted that a good physics teacher who is equipped with the use of ICT could help improve the teaching and learning of practical physics.

Previous research (Lunetta, 1998; Barton, 1998) has showed that rapid advances in technology offer a wide range of new opportunities for innovative science/physics education. Robinson (1994) supporting the use of ICT in teaching, argues that the use of the internet helps to raise pupils awareness and understanding of science and technology in the real world. Jaakkole and Nurmi (2008) carried out research on the use of simulation and laboratory work among 66 students (10-11 years) in Finland. They found that a combination of simulation and laboratory experimentation on electric circuits led to statistically greater learning gains than the use of either simulation or laboratory activities alone, and that it also promoted students conceptual understanding most efficiently. Roth et al. (1996) made a similar observation after looking at group work during the use of a modelling package in physics in a sample of Canadian schools. They noted that the computer environment contributed in significant ways to the maintenance and coordination of pupils' physics conversations. In a similar study on the effectiveness of an interactive computer simulation for teaching basic electric circuit theory with undergraduate students in a large university in the USA, Finkelstein et al. (2005) noted that students who were exposed to simulations achieved higher scores both on assessment of conceptual knowledge and on a task involving assembling a real circuit and explaining how it worked. Parkinson in his book on *Improving Secondary Science Teaching* asserts that ICT has the potential to help pupils understand graphs through the various types of software that offer graphical display (Parkinson, 2004).

Enhanced use of ICT in practical science education will be an inevitable part of the future landscape but there are barriers to adoption, most importantly the reasonable hesitations of scientists who are sceptical about the loss of physical presence and the lack of opportunity to practice traditional skills, particularly in manipulation. However, given the present lack of access to practical science in SSA, such losses would be a limited price to pay.

It is also important to address the issue of training and retraining of physics teachers in the use of educational technologies. Most of the physics teachers lack the skills to deliver effective practical physics lessons through the use of learning technologies due to their lack of exposure. School leaders and government have similar deficiencies in knowledge and experience. Education is considered through the prism of education in the 1960s and 1970s when present leaders were themselves students. Any adoption of ICT will require systemic re-education and vision.

## 7.7 Process of Change for Effective Practical Physics Teaching

Having discussed present interventions and suggestions for future reforms, it is important to look at how change could be initiated in SSA countries. It is unlikely that advocacy based on academic analysis will be sufficient to ensure that there is action. Difficulty in initiating system wide change is a familiar issue in the context of development and there are methodologies that have been designed to handle the problem. One of these is known as ‘Theory of Change’. This section will describe how a Theory of Change approach could be used to take forward reform of practical physics teaching.

Theory of Change is the description of a sequence of events that is expected to lead to a particular desired outcome. It is an on-going process of reflection to explore change and how it happens and what that means for the part we play in a particular context, sector or group of people (Vogel, 2012). According to James (2011), Theory of Change:

- locates a programme or project within a wider analysis of how change comes about;
- draws on external learning about development;
- articulates our understanding of change but also challenges us to explore it further;
- acknowledges the complexity of change and the wider systems and actors that influence it;
- is often presented in diagrammatic form with an accompanying narrative summary.

Some of James’s views on what the ToC entails are echoed in an article by Piroška (2016). She asserts that, in practice, a Theory of Change typically involves the following.

- It gives the big picture, including issues related to the environment or context that you can’t control.
- It shows all the different pathways that might lead to change, even if those pathways are not related to the program being discussed.
- It describes how and why you think change happens.
- It could be used to complete the sentence “If we do X then Y will change because.....”.
- It is presented as a diagram with narrative text. The diagram is flexible and doesn’t have a particular format—it could include cyclical processes, feedback loops, one box could lead to multiple other boxes, different shapes could be used, etc.

- It describes why you think one box will lead to another box (e.g. if you think increased knowledge will lead to behaviour change, is it an assumption or do you have evidence to show it is the case?).
- It is mainly used as a tool for program design and evaluation.

From the above claims, Theory of Change can be seen as the thinking behind how a particular intervention will bring about results.

There is a major caveat that is relevant at this point. A ‘Theory of Change’ should be constructed by those involved in promoting change. For change to occur, there must be a recognition from stakeholders that change is necessary and that it is important. There are myriad lists of the ‘rules’ of effective change management; all include the notions of acceptance of the need for change and for the creation of ownership by those involved. So, it is important that the construction of a Theory of Change should be carried out by stakeholders in Sub-Saharan Africa. The process might be orchestrated by outsiders, and authoritative professional and academic bodies have a role to play here, but it must be owned by the national governments and internal stakeholders. The orchestration may well involve a staged discussion looking in turn at; the present position (weaknesses and strengths), the desired position, the changes needed to bridge the gap, the capability of the system and its ability to effect change, and the mechanisms required to finalise a strategy and move to operationalization. This process of constructing aims and actions is the most important part of the Theory of Change.

In spite of this caveat, the rest of this section provides a brief description of a possible output of a ToC process for practical physics teaching in SSA. It will summarise key features of what might emerge from a more inclusive discussion.

### **7.7.1 Improving the Teaching and Learning of Practical Physics in SSA**

The following key assumptions underlie a Theory of Change consistent with the evidence in this study.

1. The provision of additional resources will have a positive impact in learning practical physics.
2. Reduction in physics curriculum content will give room for more hands on activities in physics.
3. Strengthening assessment of practical physics/skills will have a positive impact on teaching and learning.

4. Improved motivation of physics teachers through more pay and other welfare packages will lead to changes in attitude and improve practical physics teaching.
5. Enhanced teacher training and professional development will improve the teaching and learning of practical physics.
6. Learning practical physics through ICT will reduce costs, lead to better understanding by the learners and enhance motivation.
7. Regional collaboration among SSA countries will lead to better performance in practical physics.

Figure 7.2 shows these assumptions and associated mechanisms represented diagrammatically. Below are brief arguments relevant to the assumptions.

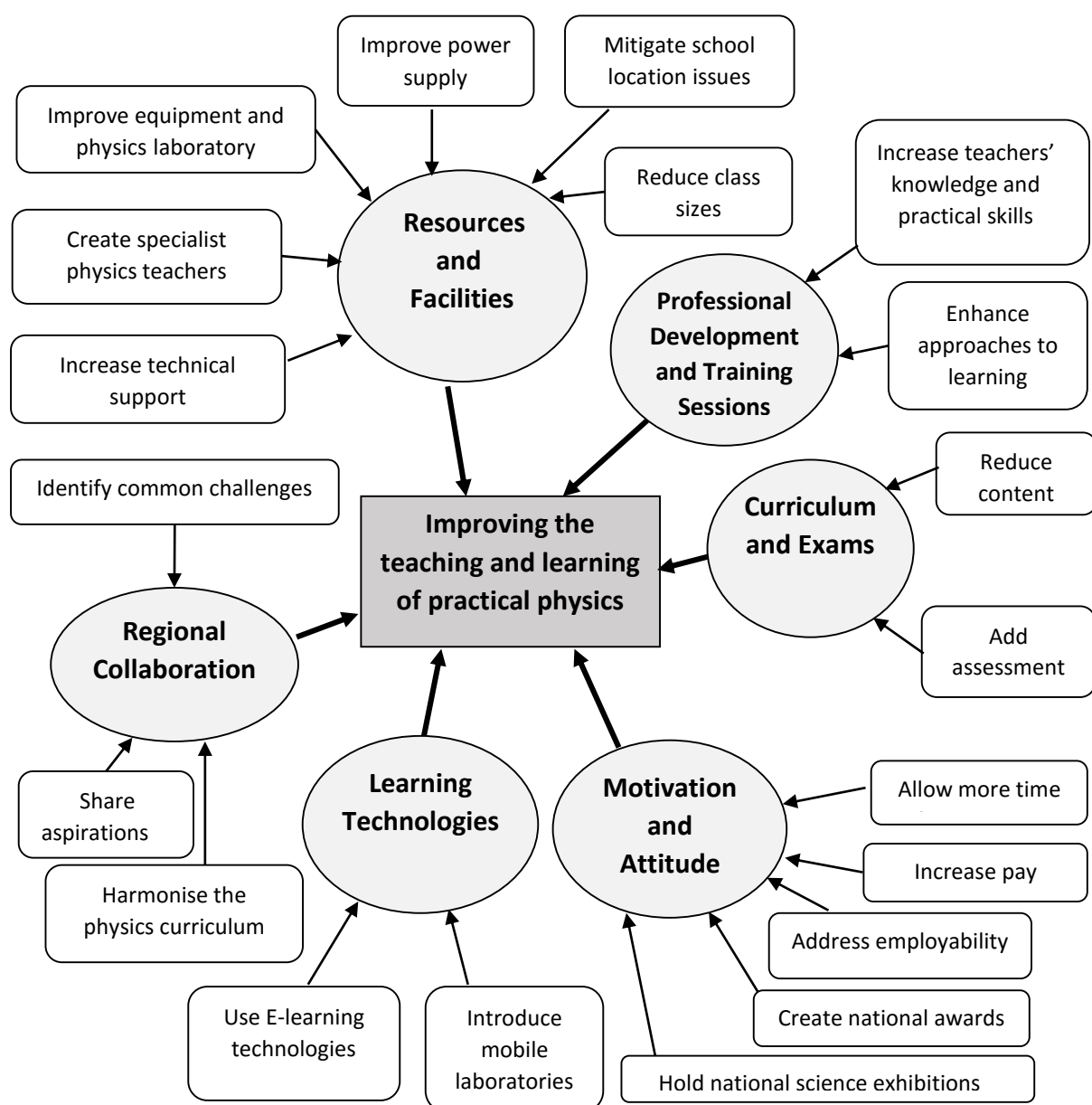
#### **1. Will reduction in physics contents give room for more practical activities in physics?**

Although reduction in content could prompt more practical activities, there is little concrete evidence that this will happen. The attitude of physics teachers towards practical physics teaching is overwhelmingly influenced by the policies of examination bodies. If recall and understanding of content continue to dominate the criteria for success in exams, teachers will continue to teach to the test and neglect practical physics. However, reduction in content will give an opportunity to re-examine the curriculum and re-orient it so that exam reform becomes more attractive. A greater focus on practical skills may be attractive to governments and students.

#### **2. How would strengthening assessment of practical physics impact on practical physics teaching?**

Assessment, both formative and summative, is an integral part of the teaching and learning process. It gives feedback to the students on their strengths and weaknesses and certifies their achievement. The fact that practical physics is either not assessed or is assessed to a very limited extent dictates the present practice in SSA. The onus to require assessments of practical physics/skills lies with government and examination bodies. They may be influenced by the potential impact on employability if educationalists can demonstrate that the skills nurtured through practical physics sessions have contemporary relevance. It is unlikely that such arguments could be made successful without reform of the practical physics curriculum.





**Figure 7.2:** A possible output from a Theory of Change process.

### **3. Will improved motivation lead to better attitudes towards practical physics teaching?**

It is a reasonable assumption that teachers who are provided with enhanced pay and status will be more willing to arrange practical physics engagement for the students. However, motivation cannot easily overcome inadequate provision of material resources, as is shown by the situation in South Africa. Indeed lack of resources is likely to be demotivating – any employee wants to have the tools required for their job. There are opportunities to enhance teacher status by awards, prizes and local science initiatives. Motivation is not an issue for teachers alone, it is also important to arouse the curiosity and interest of the learners. Students will be motivated by assessment targets but there is evidence that a relevant and stimulating curriculum can also be a powerful driver.

### **4. How does teaching through ICT lead to better understanding of practical physics?**

Research has shown that rapid advances in technology offer a wide range of new opportunities for innovation in science/physics education (Klahr et al., 2007; Zacharia, 2007; Bell, 2002). ICT could mitigate a lack of resources and improve meaningful access enormously. However, for ICT to be effective in improving student learning power, factors such as the nature of the school, school location, technical support and power availability need to be considered. Most SSA countries suffer from epileptic power supply systems - this is particularly relevant in the rural areas where students suffer many other disadvantages. Teaching through ICT in the remote areas could be expensive if operations require powered generators. However, offline or weakly connected software based around mobile phone technologies is a very real possibility. The issue of security is a major concern when using ICT in SSA schools.

ICT could be 'disruptive' in its effect on practical physics teaching in SSA. It could transform costs, access and motivations. It could provide opportunities for educationalists and researchers in SSA to generate software that meets the need of their students and enhance employability skills. Of course, it could also be regarded as a threat. Teachers may fear that learning technologies will erode their role as physics teachers and render them redundant. It would be important to assert that ICT is intended to supplement and help in the teaching-learning process.

### **5. How would regional collaboration among SSA countries enhance the teaching of practical physics?**

Creating synergy among concerned countries in SSA could lead to improvement in practical physics teaching. In West Africa, there are examination collaborations among some countries that have

improved understanding across the region. This could be extended to other SSA countries and to other areas of education. Practical experience can be shared among physics teachers in SSA, thus promoting the sense of a professional 'academy' which acts as a focus for professional development. SSA governments could develop a cadre of staff who can provide training experiences for physics teachers across the region, reducing the role of expatriate staff and volunteers.

It must be noted that no single factor can bring about the necessary change needed for practical physics teaching in Africa. So, any reform must give consideration to most of the factors highlighted in this study.

## 7.8 Summary

This chapter provided answers to the four research questions set out in the introduction to the thesis. The answers were informed by data from the research visits, examined within a framework provided by the literature, national and international statistics, reports and policy statements. The discussion attempted to identify answers that were valid across SSA whilst recognising diversity.

The first question concerned the current aims of practical physics teaching in schools in SSA. The research methodology used five aims drawn from the literature as a starting point for the dialogue with stakeholders. These aims were focused on teaching and learning. It is clear that these aims do not describe the present position in SSA. It was apparent that the most important learning and teaching role of practical work was considered to be *understanding of physics content and reinforcement of theory*. In addition the stakeholders identified roles in sustaining and motivating the interest of students and meeting economic needs and priorities. Adding these new aspirations to a reconfigured set of the original five aims led to a modified set of seven aims that described current perceptions in SSA.

The second and third research questions concerned present practice and the critical factors that influence success and failure. As might be expected the answers to these questions overlap considerably. Although there were examples of good and enthusiastic practice, the study identified several crucial areas where there are widespread difficulties. These include; lack of teachers, lack of expertise in teaching practical physics, large class sizes, shortage of material resources, unreliable access to mains power, poor maintenance and security, overambitious curricula, absence of assessment of practical work, lack of perceived relevance to employment, gender and geographical inequalities, and the daunting reputation of physics as a hard and inaccessible subject. There was a marked divergence

between national policies and current practice. For many students, there was little or no practical work included in their courses.

Identifying individual critical factors can lead to oversimplification, and, in the chapter, an attempt was made to provide a system description of the problem in the form of a multiple influence diagram. This showed not only the factors that influence directly the teaching of practical physics but also their interdependence and the indirect influences on the choices made by stakeholders. The influence diagram might be of help in considering the likely effectiveness of any intervention and in designing the intervention so as to avoid likely obstacles.

The last section in the discussion examined the various interventions that could improve the teaching and learning of practical physics in African schools. It started by reviewing recent interventions by SSA governments and international bodies and discussed their level of success. Some insight was offered into the reasons for success or failure. The section suggested several improvement actions. Some would require additional funding, e.g. the provision of adequate physics equipment and laboratories, smaller class sizes, qualified and dedicated physics teachers and laboratory assistant support, and improvements in teacher pay. Other actions could be less costly, e.g. restructuring the physics curriculum, strengthening summative assessment of practical work, enhancing teacher status, generating role models, etc. These various suggestions came from stakeholder data. Other suggestions were the introduction of regional collaboration and the adoption of ICT led approaches in practical physics teaching. This final action was suggested as a means of finessing cost and attitude obstacles.

Finally, the chapter introduced the notion of Theory of Change as a process that could be used to take forward reform of practical physics teaching in Sub Saharan African schools. The Theory of Change process would help to build local ownership and encourage the release of necessary funding.

## CHAPTER 8

### SUMMARY, RECOMMENDATIONS AND LIMITATIONS

#### 8.1 Summary

This final chapter highlights the most important findings of this study and discusses the contribution it makes to knowledge, its limitations and future work. The chapter includes some recommendations that may be of relevance to those aspiring to improve the teaching and learning of practical physics.

##### 8.1.1 Key Findings

The previous chapter discussed many findings from the study in some detail. In this chapter an attempt will be made to restate these findings as a limited number of strategically important insights.

1. Education systems in Sub-Saharan Africa are coping with formidable demographic and economic challenges. Any attempts to improve the delivery of practical physics learning must recognize these constraints. For example, there is direct competition for resource between expansion of access to primary education and improvement in specialist science provision.
2. Practical physics is not assessed effectively in any of the countries visited. There is tacit acceptance of the weakness of delivery of practical science. It is unrealistic to expect scarce resource to be allocated to a curriculum area that is not assessed for qualification.
3. There are many barriers to effective teaching and learning of practical physics. Although attention is often focused on the undoubted lack of resource and professional skills, there are also organizational and social issues (e.g. lack of time allocated to practical work, security of equipment, transport problems, limited relevant employment opportunities, low teacher pay, etc.) Systemic change will require broadly based initiatives.
4. Although there is broad understanding of student-centred approaches, teaching in Sub-Saharan Africa is overwhelmingly content led. This is an understandable response to the pressure of large classes but may also be linked to an understanding that the teacher/student relationship is based on hierarchy and authority. The dominance of content led thinking inhibits effective delivery of rich practical experiences.
5. Demand for physics and practical physics is affected by the limited expectations of some students and, in many countries, by the lack of directly relevant employment opportunities.

Physics is still seen as a subject that is difficult and is of most relevance to male and privileged students.

6. Very few stakeholders have any experience or understanding of the effective use of technology in education. This would affect the viability of any reform based on the use of technology.

Although there is diversity between the countries visited, the issues listed above are relevant to all. Given the broad similarities in demographic and economic circumstances, it is reasonable to expect that the findings are broadly appropriate across the region. However, the political and social differences between countries may be such that implementation of reform might take different routes.

Many ways of improving the quantity and quality of practical physics teaching were identified by stakeholders. The suggestions made address the direct barriers that these stakeholders face. The most common suggestions were:

- a) Building more laboratories and acquiring modern equipment
- b) Reducing the physics curriculum content
- c) Strengthening the assessment requirements for practical work.
- d) Improving the professional training, pay and motivation of physics teachers

In addition, there were two more radical suggestions; regional collaboration and the adoption of ICT methods in the teaching of practical physics.

This study has revealed the stakeholder consensus on the accepted aims of practical physics teaching in Sub-Saharan Africa. The most prominent aims are: understanding of physics concepts, reinforcing the theory learnt in physics, acquiring skills, exploring and discovering physics laws, motivating students, nurturing the personal development and life skills of students and contributing to national economic development (Figure 5.10, 5.11, 5.3 and Table 6.1, 6.5). It is important to note that stakeholders are realistic in recognizing that current practice cannot deliver these aims.

These aims are somewhat different from those found in the literature on practical physics education, notably in the shifting of the balance towards practical work as an adjunct to learning of facts and theory as opposed to having value in its own right. There is a debate to be had about whether these aims are desirable in Sub-Saharan Africa.

## 8.2 Recommendations

There are clear indication from this study that laboratory and practical physics teaching is not prioritized by those allocating resources even though national curriculum documents highlight the important of practical physics. This lack of commitment is likely to influence the success of any initiative aimed at promoting practical physics in SSA.

It is also clear that the factors that influence present practice and the possible ways of effecting change are systemic. The system analysis in the study (Figure 7.1) revealed that the factors are heavily interdependent and if change is going to be nucleated most effectively, it is necessary to move beyond separate themes and look more broadly at the system as a whole

Within these constraints it is possible to make some recommendations that, if acted upon, would promote improvements in the teaching of practical physics.

1. Countries wishing to improve practice should undertake a broadly based audit of existing practice taking into account the full range of barriers and drivers. The audit would include issues such as; resources, professional skills, curriculum design, and assessment policy as well as employment opportunity and motivation. The audit could lead into a theory of change process.
2. The physics curriculum should be reviewed to explore reduction of content to allow teachers to spend more time on practical activities and to better reflect the identity of physics as a subject that encompasses both theory and practice. A complementary review should explore how the practical work might be less prescriptive and more relevant to future employability. This is likely to involve a greater focus on technological physics and instrumentation.
3. Initial training and continuous professional development of teachers should prioritise teaching of practical physics. Such training should be aimed at teachers achieving international standards in their professional skills. It will lead to increased teacher confidence and more effective use of resources. CPD must be targeted to the needs of the particular teacher. It is necessary to develop greater practical teaching skills in qualified physics specialists and to enhance practical teaching skills and subject knowledge in non-specialists and unqualified teachers.
4. Assessment of practical skills should be required for qualification and used formatively. Without such change all other changes will be ineffective.

5. Government funding should be allocated to build, equip and maintain adequate school laboratories. The funding required may be minimized by the use of readily available technologies and by the pooling of resources. There may be opportunities for partnerships with the commercial sector in addressing such resource needs. Funding should be sensitive to local needs and capabilities. So, for example, there is a case for placing more elaborate contemporary equipment in centres of excellence with robust power and support and for providing low-cost and easily maintained equipment to demonstrate physics principles in rural disadvantaged schools.
6. Physics teacher should be encouraged to adopt the use of learning technologies and open source software in the teaching and learning of practical physics. The use of ICT in practical physics will be of great help in the resource disadvantaged schools of SSA. It will take advantage of rapid expansion in access to mobile technologies and information systems.
7. Physics teachers across Africa should be encouraged to use social media to develop a closer association that will spread effective practice. A professional support network might be an intrinsic element of CPD with monitoring and mediation by experienced staff both within country and through expatriate links.
8. Teacher motivation should be enhanced by recognition of success in the delivery of practical physics. This might involve pay, allowances, status, or prizes.
9. Students should be encouraged and motivated to learn practical physics by placing employability and relevant inquiry in the foreground. The importance of practical skills should be recognized explicitly.
10. Countries should explore the possibility of physical resource sharing across the sciences and institutions. This is not a panacea as previous attempts to share resources have had limited success because of issues such as ownership conflicts, transport limitations and organisational overheads. Nevertheless, a sensitively designed approach to sharing has potential to mitigate resource limitations and encourage transfer of expertise.



### 8.3 Limitations of the Study

This study had a number of limitations. The data were gathered primarily from physics teachers, students and key stakeholders from just four countries out of fifty-four countries in Africa. Although the countries visited in the study span through West, South and East Africa and were chosen to represent a range of sizes and stages of development, the data is limited and it is possible that key features have been missed. In particular field data was only gathered on Sub Saharan Africa and there are distinct cultural differences between the North and the South, e.g. dominant religion, external influences etc. The perspectives that were presented by stakeholders in this study may or may not be similar to those that would be presented by other stakeholders from other countries outside the orbit of this study.

In the four countries visited in the study, a purposive sampling techniques was used to select the participants for the study and this might limit the generalizability of the findings. It is possible that physics teachers from different schools may have offered important information which would have been relevant to the study.

The study also adopted a mixed method approach to gather data. This offered significant advantages. The quantitative and qualitative study provided different levels of detail which complemented each approach in answering research questions. The qualitative method enabled the researcher to gain more detailed and richer data in the form of comprehensive written description that were absent from the survey data. The major limitation in the adopted approach was the lack of structured classroom observations during the research visits. These would have provided further insight into the present practice in practical physics teaching and learning but were operationally impractical.

The views of physics students in the study were used to reinforce and validate the teachers' responses. However, the use of focus group interviews may have affected the findings of the study since students' responses may be influenced by personal feelings, positive and negative, for their teachers and anxiety that teacher attitudes may be affected by the views expressed. To mitigate this possible effect, all students were assured of the confidentiality of the data gathered and the students' names and identifying details were anonymized.

It is relevant to consider whether this study of practical physics in four countries within one sub-continental region provides any insight into practical science teaching in other subjects and other countries and regions. Relevance to other countries within SSA is almost certain. These countries have many environmental and social similarities with the countries visited. The consistency of the findings in

the four somewhat varied countries included here suggests that they are likely to serve as indicators of what is happening in other schools and countries in the continent of Africa. Similarly, extrapolation to other science subjects within SSA is likely to be successful. In several countries, the sciences are taught together and have similar resource and attitudinal problems. However, there may be significant differences in that chemistry and biology have stronger employment drivers in some areas. This would need to be explored.

The analyses carried out, particularly, the systems description, are likely to be partially relevant to other less economically developed countries with similar demographics and resource constraints, e.g. in South America. Many of the significant factors are the same – class sizes, teacher centred learning, resources, staff shortages, lack of CPD etc. However, in some countries there may be different social attitudes that affect the strategies that might be used for remediation. For example attitudes to authority might influence the success of top-down solutions and religious beliefs might affect attitudes to both science and inquiry.

The findings have some relevance to developed countries. It may well be that the significant problems in SSA bring into sharper focus issues that are somewhat hidden in the teaching of practical physics in the UK and elsewhere. For example, the influence of practical exams (or lack of exams) on learning has been noted on many occasions. Recently, in the UK, there has been renewed focus on curriculum content. Will this affect attitudes to practical science? Such issues are worth further consideration.

## **8.4 Contribution to Knowledge**

This is the first broadly based study into the aims and present practice in the teaching and learning of practical physics in Africa. The study generated considerable data and involved large numbers of stakeholders.

The study has revealed the ‘true’ stakeholder perceptions of the aims of teaching practical physics in Africa’s schools. Most significantly, it has shown that work is subordinated to the assimilation of content and the understanding of theory. In effect there is no focus on the specific learning potential of practical work.

The resource shortage in schools in Africa is a well understood problem. This study has served to reinforce this understanding, to emphasise the level of deficiency and to link it to issues such as

maintenance and security. It has become clearer that there is a long history of resources being unused because of poor maintenance, other demands made on teachers and anxieties over security.

Although it was anticipated that the weak professional skills of teachers might limit their ability to teach practical physics, the study has shown that the practical skills of teachers are almost completely absent. Although many have a solid understanding of physics theory, a large number have almost no experience or expertise in using scientific equipment or carrying out experiments. This is true of even the most basic equipment. They cannot teach effectively skills that they do not possess.

The study has shown the existence of a gulf between policy and practice in practical physics education. Although it is declared to be of importance, it is not resourced, timetabled or assessed. There is little evidence that the teaching of practical physics is a felt priority.

Motivation of students is a major issue. Physics is often seen as a difficult and abstract subject with little connection to wider life or future employability. The observation made by some students that a physics education only led to a job as a poorly paid physics teacher was striking. The unimaginative and formulaic practical physics sessions that are offered reinforce these impressions. Given these disadvantages, it is surprising and gratifying that many students expressed an enthusiasm for more practical work.

In many areas, Africa is at the forefront in the effective use of mobile technologies. Students use social media avidly and many businesses are run through ICT. Given this background it is surprising that teachers have little or no knowledge of the developments in learning technologies that might help them to deliver effective learning, including within practical physics.

Previous studies have explored how deficiencies in resource or professional skills might be affecting the quality of practical physics teaching. This study has revealed that practical physics teaching is subject to many influences. Any attempt to understand and reform must recognise the systemic nature of the problem.

While previous studies reveal that availability of resources and laboratories are pressing issues influencing the teaching and learning of practical physics, this present study also revealed that students' beliefs about the nature of physics and mathematics, assessment of practical physics, background knowledge in physics and mathematics, and regional collaborations and opportunities for continuous professional development are also important for the effective teaching and learning of practical physics in Africa's schools

## 8.5 Suggestions for Further Research

Based on the findings from the study, the following suggestions are provided for further studies:

1. The teachers who participated in this study commented that the physics curriculum is overloaded with content and that this hinders them from engaging the students in practical physics. This raises the issue of whether the current physics curriculum in schools across Africa is adequate to meet the needs and aspirations of the region. Further studies will be required to establish the appropriate physics curriculum and to identify the practical work that should be included. It may be that the curriculum, should recognize the level of local economic development and employment needs.
2. The present research could be replicated in other science subject areas such as Biology and Chemistry in secondary schools, so as to further investigate the findings in the present study.

## 8.6 Final Thoughts

Despite the fact that practical work is a core part of the physics curriculum in developed countries, there is little evidence of effective practical work in the physics teaching and learning process in Africa. The study has found that students can pass through high schools without practical exposure and still achieve a good grade in physics. Students hardly acquire any practical skills that could make them of employable value throughout their studies at both high school and tertiary level in Africa. This lack of practical skills is a concern. Africa might continue to produce physics graduates with limited ability to generate new ideas and solve Africa's practical problems if nothing is done to the present practice in practical physics teaching as revealed in this study. This might be counterproductive to the development of science and technology in Africa in the 21<sup>st</sup> century.

Although the problems are formidable, ICT may provide a transformative input. Use of robotic laboratories, external data generation, and simulations is having a major impact in practical science teaching in the developed world. Africa could make use of the resources in accessible collections and contribute back to the collections experiments of particular relevance in an African context. This could lead to enhanced access at lower cost with the opportunity to incorporate practical work that has contemporary relevance. Such a change may be politically attractive and could enhance both teacher and student motivation.

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## APPENDICES

### Appendix A: Teachers' Survey Questionnaire

ADVANCING PRACTICAL PHYSICS IN AFRICAN SCHOOLS

TEACHERS QUESTIONNAIRE

#### SECTION A. Background Information

##### About you

Your Name (optional).....

Sex: Male ☐ Female ☐

Age: Under 30 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60 and above ☐

Qualification: please tick all the boxes that identify your qualifications.

First degree in Education ☐ Pre Degree certificate in Education ☐ First degree others ☐

Any additional qualification: PGDipE ☐ MSc ☐ MEd ☐ PhD ☐

The subject area of your qualification: Physics ☐ Chemistry ☐ Biology ☐ Maths ☐

Other (please specify) .....

By the end of this school year, how many years will you have been teaching in total? .....

##### About your school

Name of School: .....

Types of School: Boys only ☐ Girls only ☐ Co-educational ☐

School Location: Rural ☐ Suburban ☐ Urban ☐

How many specialist physics teachers are there in your school? .....

What is the student population of your school? .....

How many students are enrolled in physics as a separate subject in your school? .....

## SECTION B: About School Facilities

This section asks you about the availability of resources and facilities in your school. To what extent do you agree with the following statements?

Resources and Facilities	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
We have a dedicated physics laboratory.					
Our equipment and instruments are relevant and modern.					
We have sufficient laboratory facilities for practical work.					
The state of repair of laboratory facilities is satisfactory					
We have laboratory assistant support					

Please add any comment you feel is appropriate about the practical physics facilities at your school.

.....

.....

## SECTION C. About assessment at your school

This section examines the level of your assessment in the teaching and learning of physics. It involves assessment for formal qualification and to assess progress and guide students.

1. Which physics qualification(s) are your students studying for?

.....

2. Please rank in order of importance what is required for students to be successful in studying for these qualification(s).

Qualification Requirements	Rank
Good knowledge of physics content.	
Understanding of physics content.	
Application of the knowledge of physics, e.g. in problem solving.	
Skills in practical physics.	

3. Which assessment methods are used for the award of qualifications and to assess student progress? Please tick all boxes that apply for each and indicate the order of importance for the boxes you have ticked, e.g. ✓1, ✓2

Assessment method	Formal qualification	Student progress
Written assignment		
Computer based test		
Problem sheet		
Practical/lab work observations		
Project/field work observations		
Lab notebook or write-up of experiment		
Examination		

4. Please add any comment you would like to make on the assessment of *practical physics* for formal qualification purposes or for checking of progress.

.....  
 .....  
 .....

## SECTION D: Current Practice

This section looks at the environment in which the teaching of physics takes place. To what extent do you agree with the following statements as descriptions of your experience as a physics teacher?

	<b>Strongly agree</b>	<b>Agree</b>	<b>Undecided</b>	<b>Disagree</b>	<b>Strongly disagree</b>
Teachers have sufficient opportunity to attend seminars and workshops to improve their teaching.					
Discussion between students does not help learning.					
Students' existing knowledge is assessed to guide lesson planning.					
Students are encouraged to ask questions.					
Few students gain the skills of independent thinking.					
The curriculum is focused on preparing students for higher education.					
Most teachers of physics have good knowledge of physics content.					
Teachers are supported well by the school administration.					
Many teachers have limited knowledge and skills in teaching practical work.					
There is insufficient time to explain topics in the required depth.					

### SECTION E. About teaching techniques

There are many ways of teaching practical physics. In this section, we are seeking your opinion about the approaches you believe are most effective. Please put a tick against the **five** approaches that you think are most important and indicate how often you believe this approach should be adopted.

Physics should be taught this way	All the time	Most of the time	Sometimes	Not often	Never
Students should follow a sequence of pre-defined steps in carrying out experiments.					
Students should investigate their own questions and plan their own experiments.					
Whole-class discussion should occur after practical activities to summarise the main ideas.					
Practical work should be used to illustrate the concepts that have been introduced previously.					
Practical work should be carried out by students before the theory is introduced, i.e. discovery learning.					
Students should be focused on the importance of getting the accepted answer from their measurements.					
All students should be exposed to the same practical curriculum but be allowed to progress at their own pace i.e. individualized instruction					
Students should be directed to investigate the natural world they see around them.					

### SECTION F: About the aims of teaching practical physics

In this section, five possible aims of practical work in physics are listed. Please rank these aims in order of importance from 1 to 5. The most important aim should be ranked "1" followed by the next most important '2' etc.



<b>Aims of physics practical work</b>	<b>Rank</b>
To develop skills in the design of experiments and investigations.	
To encourage skills of working together in a scientific context.	
To provide a context for the development of mathematical skills.	
To make new observations about the natural world.	
To encourage the development of skills in the design of instruments.	

You may feel that an important aim has not been listed above. If so, please add any such aim below and indicate where it would sit in the ranking you have provided.

.....  
 .....

### **SECTION G. About obstacles to achieving the above aims**

In this section, we look at the factors that affect the teaching & learning of practical physics in schools. Please tick and rank the five factors that cause the greatest problems in teaching practical physics (1 is most important).

<b>Practical work is affected most by the following.</b>
Lack of well-equipped laboratories.
Insufficient time for teaching.
Large class size.
Overloaded curriculum.
Lack of professional development for teachers.
Poor remuneration.
Inadequate teacher motivation.
Lack of laboratory assistant support.
Lack of support from the school.
Insufficient availability of qualified and dedicated teachers.
Any other factor not listed? <i>Please tick this box and explain below</i>

.....  
 .....

What measure(s) do you think should be taken to overcome the obstacles mentioned above to improve the teaching and learning of practical physics in schools?

.....

.....

.....

.....

.....

.....

.....

.....

.....

THANK YOU

## Appendix B: Students' Survey Questionnaire

### ADVANCING PRACTICAL PHYSICS IN AFRICAN SCHOOLS

#### STUDENT QUESTIONNAIRE

Dear Student,

This questionnaire asks for your opinions about the teaching and learning of physics in your school.

There is no right or wrong answer to any of the questions. This is not a test and your answers will not affect your scores and grades. Do not write your name, or any other comments that could identify you on this questionnaire. Your answers will remain confidential and will not be shared with anybody at your school. Any reports about this research will not name any teachers, students or schools. By completing the questionnaire you are agreeing to take part in this research.

This research is about practical work in physics across Africa's schools. Practical work in secondary schools physics usually takes the form of laboratory sessions, demonstrations, fieldwork, investigations and excursions.

#### SECTION A. Background Information

##### About you

Sex: Male ☐ Female ☐ Age: .....years. Your class level:  
.....

##### About your school

Name of School: .....

*School location:* Rural ☐ Suburban ☐ Urban ☐ *Type:* Boys only ☐ Girls only ☐ Co-  
educational ☐

### Section B. **About Teaching and Learning activities**

This section asks about your learning in the physics classroom. What percentage (%) of your time learning physics is filled by the following activities? (Total must be equal to 100%)

Teaching and learning activity	Percentage of class time
Listening to the teacher explaining.	
Engaging in whole class discussion with the teacher and other students.	
Copying the teacher's notes.	
Working on your own from a textbook.	
Doing practical and activity work individually or in a small group.	
Listening to teacher demonstrating to the whole class.	
Any other activities not listed above (optional). If so, please describe .....	

### Section C: **About Attitude to Practical Work**

This section examines your attitude to the teaching and learning of practical physics in your school.

Please write answers to these three questions in the space provided

1. What do you enjoy most about practical activities in your physics lessons?

.....

2. What do you least enjoy about practical activities in your physics lesson physics?

.....

3. What could be done to help you learn more about practical physics in your school?

.....

**To what extent do you agree with the following statements? If the statement does not apply to you, please tick the n/a box.**

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Undecided</b>	<b>Disagree</b>	<b>Strongly disagree</b>	<b>n/a</b>
I enjoy doing practical work in physics.						
I am able to learn well from practical work in physics lessons.						
I prefer non-practical work to practical work in physics lessons.						
Doing practical work is my favorite part of physics lessons.						
Practical work helps me understand physics.						
I find practical work in physics hard.						
What I learn from physics practical will be useful when I leave school.						
The practical work that we do shows me how physicists work in the real world.						
I would prefer to learn physics without having to do practical work.						
I enjoy the freedom I have during practical work in physics lessons.						
Practical is an important part of learning physics.						
My school has the resources needed for my physics practical work.						
We do physics practical work regularly.						

THANK YOU

## Appendix C. Interview Questions for Stakeholders

Interviews will be limited in duration (target 20 minutes) and will be designed to be as open as possible, i.e. using an ethnographic style. Pre-prepared and tailored follow up questions will be used to prompt responses. The interviews will be audio-recorded and transcribed for subsequent analysis.

### *Curriculum Definition and Delivery Stakeholders (Physics teachers and Educationalist)*

1. What is the school practical physics curriculum designed to achieve?  
*Follow up if required on balance between skills acquisition and knowledge.*
2. How successful are the students in learning about practical physics?  
*Follow up asking for an example of success or weakness*
3. What influences success in teaching practical physics?  
*Follow up if required asking for elaboration of a factor that has been identified.*
4. How could practical physics teaching be improved?  
*Follow up if required asking what will help or hinder the suggested changes.*

### *Learning Stakeholders (Students)*

1. Tell me what you do in practical physics classes.
2. What sort of things are you are trying to learn?
3. Do you like studying practical physics?
4. How well are you and your class mates doing?
5. What is the best physics practical session you have had?
6. What would your ideal practical physics session look like?

## Appendix D: HREC Favourable Opinion



The Open University

From Dr Duncan Banks  
Chair, The Open University Human Research Ethics Committee  
Email duncan.banks@open.ac.uk  
Extension 59198  
  
To Femi Babalola Emmanuel, Department of Physical Science,  
Faculty of Science  
  
Subject "Advancing Practical Physics in Africa's Schools."  
Ref HREC/2014/1606/Babalola/1  
AMS ref n/a  
Submitted 1 February 2014  
Date 10 February 2014

### Memorandum

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, has been given a **favourable opinion** by the Open University Human Research Ethics Committee. Please note that the OU research ethics review procedures are fully compliant with the majority of grant awarding bodies and their Frameworks for Research Ethics.

Please make sure that any question(s) relating to your application and approval are sent to [Research-REC-Review@open.ac.uk](mailto:Research-REC-Review@open.ac.uk) quoting the HREC reference number above. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Regards,

Dr Duncan Banks  
Chair OU HREC

## Appendix E: Information Letter for Headmaster/Mistress



Department of Physical Sciences

Faculty of Science

Milton Keynes, United Kingdom

Information letter for Headmaster/mistress

Dear Sir/Ma,

I have the honour to state that I am a PhD research student at the Department of Physical Sciences of the Open University, Milton Keynes, United Kingdom. My research topic is **“Advancing Practical Physics in Africa’s Schools”** under the supervision of Profs. Steve Swithenby, Robert Lambourne and Bamidele Olaniyi. This is a project that is being sponsored by the Institute of Physics, UK, as part of their commitment to effective physics education in Africa. The most relevant part of that commitment is that the IoP is working with physics teachers in nine (9) African countries to improve the teaching of practical physics

The intended participants for the study are the head teachers, Head of Science Department, Physics teachers and Students. It will also involve curriculum officers, physics examiners and other key stakeholders in physics education. The proposed means of data collection for the study will involve the distribution of questionnaires to both the teachers and students. Also, all stakeholders mentioned above will be interviewed.

The primary purposes of the study is to examine the objectives of the practical physics curriculum, assess the current classroom practice in practical physics education in African schools, and determine the critical factors that influence success in the teaching of practical physics and suggest ways of improving the teaching of practical physics in African schools

It is envisaged that this study will provide physics educators, physics curriculum planners and governments with detailed information about the current practice in physics teaching and learning in Africa’s schools, and ways of improving the situation. It is intended that this study will also help in planning and formulating further policies for physics education in Africa.

I am therefore requesting for your kind approval in gaining access to the physics teachers and science students in your school. I hope that science education will benefit from your rich experiences. However, participation in the study is voluntary. If you agree to teachers in your participating, he/she



will have the right to withdraw from the project at any time without penalty. If they withdraw, I will use my best endeavors to remove any of the information relating to them from the project.

The project has been approved by the Open University's Ethics Committee. Your views will be used only for the purpose of research and any information you provided will be anonymised. All participants will receive a copy of either the full report or a summary of the findings of the study.

Any questions concerning this research can be directed to me Babalola Femi Emmanuel at the Centre for Distance Learning Obafemi Awolowo University, Ile Ife, Nigeria or through my phone number: +2348038052836, email: [femi.babalola@open.ac.uk](mailto:femi.babalola@open.ac.uk) or either of my supervisors can be contacted at Open University Professor Stephen Swithenby on ([steve.swithenby@open.ac.uk](mailto:steve.swithenby@open.ac.uk)), Professor Robert Lambourne ([robert.lambourne@open.ac](mailto:robert.lambourne@open.ac)) and my O.A.U supervisor Professor Bamidele Olaniyi ([hbolaniyi@yahoo.co.uk](mailto:hbolaniyi@yahoo.co.uk)).

**Thank you for being part of this important study**

Yours faithfully,

Babalola Femi.

## Appendix F: Information Letter for Teachers



Department of Physical Sciences

Faculty of Science

Milton Keynes, United Kingdom.

Dear Teacher,

I have the honour to state that I am a PhD research student at the Department of Physical Sciences of the Open University, Milton Keynes, United Kingdom. My research topic is “Advancing Practical Physics in Africa’s Schools” under the supervision of Profs. Steve Swithenby, Robert Lambourne and Bamidele Olaniyi. This is a project that is being sponsored by the Institute of Physics, UK, as part of their commitment to effective physics education in Africa. The most relevant part of that commitment is that the IoP is working with physics teachers in nine (9) African countries to improve the teaching of practical physics

The attached questionnaire has been designed for the purpose of data collection. As one of the stakeholder in physics education, I request you to please fill the attached questionnaire which seeks your opinions and concerns about teaching and learning of practical physics in secondary schools. In addition, we are hoping to carry out follow-up interviews with a number of teachers. If you are willing to be contacted for a short conversation, please add your contact details when completing the questionnaire.

The primary purposes of the study is to examine the objectives of the practical physics curriculum, assess the current classroom practice in practical physics education in African schools, and determine the critical factors that influence success in the teaching of practical physics and suggest ways of improving the teaching of practical physics in African schools

It is envisaged that this study will provide physics educators, physics curriculum planners and governments with detailed information about the current practice in physics teaching and learning in Africa’s schools, and ways of improving the situation. It is intended that this study will also help in planning and formulating further policies for physics education in Africa

The project has been approved by the Open University's Ethics Committee. Your views will be used only for the purpose of research and any information you provided will be anonymised. All participants will receive a copy of either the full report or a summary of the findings of the study. I will be extremely grateful to you for this cooperation.

Yours faithfully,

Babalola Femi

## Appendix G: Consent Form



### DEPARTMENT OF PHYSICAL SCIENCES FACULTY OF SCIENCE

Consent form for persons participating in a research project

**ADVANCING PRACTICAL PHYSICS IN AFRICA'S SCHOOLS**

Name of participant:

Name of principal investigator(s): **Femi Babalola**

1. I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written statement in plain language to keep.
2. I understand that my participation will involve interviews and questionnaires and I agree that the researcher may use the results as described in the plain language statement.
3. I acknowledge that:
  - (a) the possible effects of participating in this research have been explained to my satisfaction;
  - (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data I have provided;
  - (c) the project is for the purpose of research;
  - (d) I have been informed that the confidentiality of the information I provide will be safeguarded subject to any legal requirements;
  - (e) I have been informed that with my consent the data generated will be stored on encrypted portable device or media and will be destroyed after five years;
  - (f) if necessary any data from me will be referred to by a pseudonym in any publications arising from the research;
  - (g) I have been informed that a summary copy of the research findings will be forwarded to me, should I request this.

I consent to this **Interview** being audio-taped/video-recorded

☐ **yes**   ☐ **no**  
(please tick)

I wish to receive a copy of the summary project report on research findings

☐ **yes**   ☐ **no**  
(please tick)

Participant signature: \_\_\_\_\_

Date: \_\_\_\_\_

Note: If you have any concerns about this research and will like to discuss them with an independent person, you may contact Prof. Stephen Swithenby or Prof. Robert Lambourne both of The Open University, Walton Hall, Milton Keynes, United Kingdom, MK7 6AA.

Emails: [steve.swithenby@open.ac.uk](mailto:steve.swithenby@open.ac.uk) and [robert.lambourne@open.ac.uk](mailto:robert.lambourne@open.ac.uk)

#### PI DETAILS

Name: Femi Babalola

Unit/Faculty: Department of Physical Sciences, Faculty of Science

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## Appendix H: Research Approval Letter

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**REFERENCE:** 20150116-42081

**ENQUIRIES:** Dr A T Wyngaard

Mr Femi Babalola  
Department of Physical Science  
The Open University  
Milton Keynes  
MK7 6AA  
United Kingdom

**Dear Mr Femi Babalola**

### **RESEARCH PROPOSAL: ADVANCING PRACTICAL PHYSICS IN AFRICA'S SCHOOLS**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **28 January 2015 till 28 February 2015**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services  
Western Cape Education Department  
Private Bag X9114  
CAPE TOWN  
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

**Directorate: Research**

**DATE: 17 January 2015**